No. 2014-1267

In the
United States Court of Appeals
for the Federal Circuit

RELUME CORPORATION TRUST AND DENNY FOY, SHAWN GRADY AND MARIE HOCHSTEIN, TRUSTEES,

Plaintiffs-Appellants,

v.

GE LIGHTING SOLUTIONS, LLC,

Defendant-Appellee.

Appeal from the United States District Court
for the District of Delaware, Case No. 1:12-cv-00871
The Honorable **Leonard P. Stark**, Judge Presiding

BRIEF OF PLAINTIFFS-APPELLANTS RELUME CORPORATION TRUST, ET AL.

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Dated: March 31, 2014

CERTIFICATE OF INTEREST

Counsel for Relume Corporation Trust and Denny Foy, Shawn Grady and Marie Hochstein, Trustees, certifies the following:

1. The full name of every party or amicus represented by me is: Relume Corporation Trust and Denny Foy, Shawn Grady and Marie Hochstein, Trustees.

2. The name of the real part in interest (if the party named in the caption is not the real party in interest) represented by me is: Relume Corporation Trust and Denny Foy, Shawn Grady and Marie Hochstein, Trustees.

3. All parent corporations and any publicly held companies that own 10 percent or more of the stock of the party or amicus curiae represented by me are: None.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this Court are:

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STATEMENT OF RELATED CASES

Pursuant to Federal Circuit Rule 47.5, Relume Corporation Trust and trustees Denny Foy, Shawn Grady, and Marie Hochstein (collectively "RCT") state that:

1. No appeal in this case has ever been heard before this Court or any other appellate court;

2. No other case known to RCT's counsel will directly affect or be directly affected by this Court's decision in the pending appeal.

STATEMENT OF JURISDICTION

This is an appeal from a final judgment in a patent infringement case entered on February 21, 2014 by Judge Leonard P. Stark of the United States District Court for the District of Delaware in *Relume Corporation Trust, et al. v. GE Lighting Solutions, LLC*, Case No. 1:12-cv-00871-LPS. The statutory basis for the District Court's subject matter jurisdiction was 28 U.S.C. §§ 1331 and 1338(a). The statutory basis for this Court's appellate jurisdiction is 28 U.S.C. § 1295(a)(1). The Notice of Appeal was timely filed on January 28, 2014, following the District Court's grant of summary judgment and docket entry closing the case, and became effective as of the February 21, 2014 final judgment by operation of Federal Rule of Appellate Procedure 4.

STATEMENT OF THE ISSUES

The federal common law provides an implied-in-law prohibition against the assignability of patent license rights, absent express consent by the patentee. The question presented is whether a generic "successors and assigns" clause that mentions the agreement as a whole, but not the license term itself, fails as a matter of law to constitute such consent. If not, the question becomes whether it fails to constitute consent when other parts of the agreement show the parties' intent to withhold assignability from the license term, while granting it to other terms including a restricted covenant not to sue.

STATEMENT OF THE CASE

This appeal arises out of the District Court's grant of GE's Motion for Summary Judgment on Plaintiffs' Sole Claim - Patent Infringement. (A0010; A0013; A0001-9.) The District Court found that GE was licensed under the patent-in-suit, United States Patent No. RE42,161 ("the '161 Patent"). (A0004; A0009.)

I. THE PARTIES AND THEIR PREDECESSORS

Appellant RCT is the assignee of the '161 Patent, which issued on February 22, 2011, and which claims an assembly for powering LEDs as used in traffic signals. (A0026.) The '161 Patent is a reissue of United States Patent No. 5,661,645 ("the Original '645 Patent"), which the USPTO granted August 26, 1997 to Peter Hochstein, and which Mr. Hochstein assigned to Relume Corporation

("Relume"), a subsidiary of Relume Technologies, Inc. which still manufactures LED lighting products today.

The Original '645 Patent was one of two patents asserted by Relume against Ecolux, Inc. ("Ecolux") in 1998 in the United States District Court for the Eastern District of Michigan. (A0180.) Relume and Ecolux resolved that action in December 1999 by entering into a Settlement Agreement ("the Settlement Agreement") under which Ecolux was granted various rights, including an unrestricted non-exclusive license to practice the patents-in-suit and any reissues of those patents. (A0180-86.) The parties do not dispute that the '161 Patent is within the scope of the unrestricted license provision within the Settlement Agreement. The Settlement Agreement simultaneously granted more limited rights (a covenant not to sue under the '161 Patent on a finite preexisting pool of products) to Ecolux's "successors and assigns" - a category of future entities not mentioned in the license provision itself. (Id.)

In August 2000, Appellee GE, then operating under the name GELcore, LLC, acquired the business and substantially all the assets of Ecolux under an Asset Purchase Agreement. (A0192-93.) As part of that transaction, Ecolux explicitly assigned the Settlement Agreement with Relume to GE. (A0192-93; A0209; A0241; A0243.) The Asset Purchase Agreement required Ecolux to provide an opinion of counsel of full assignability of the Settlement Agreement.

(A0222, Section 6.2(k).) But Ecolux did not, as the exhibit slated to hold such an opinion does not contain any statement, opinion, suggestion or insinuation, in any form whatsoever, that the Settlement Agreement or any of its parts was assignable. (A0307, Exhibit 6.2(k).) The parties do not dispute that GELcore, LLC proceeded with the transaction despite this flaw in the closing documents. The District Court did not address this awareness by GELcore, LLC (*i.e.*, by GE) of Ecolux's decision not to provide the promised legal opinion in its memorandum opinion.

II. THE PROCEDURAL HISTORY OF THE CASE

In July 2012, Appellant, RCT, brought the underlying action against Appellee, GE, asserting infringement of the '161 Patent through GE's sale of LED signal modules. (A0046-52.) On February 19, 2013, GE filed its Second Amended Answer, Affirmative Defenses and Counterclaims, in which it asserted that it was licensed under the '161 Patent. (A0075; A0080.)

GE sought leave, unopposed, to file for early summary judgment on the grounds that it had an unrestricted license under the '161 Patent. (A0022.) The District Court granted GE's request, and on May 9, 2013, GE moved for summary judgment. (A0002; A0022.) On August 23, 2013, the District Court held a consolidated hearing on claim construction and GE's motion for summary judgment. (A0002; A0025.) On December 30, 2013, the District Court granted GE's Motion for Summary Judgment on Plaintiffs' Sole Claim - Patent

Infringement. (A0001-10.) *Relume Corp. Trust v. GE Lighting Solutions, LLC*, 2013 U.S. Dist. LEXIS 182537 (D. Del. Dec. 30, 2013).

III. THE SETTLEMENT AGREEMENT AT ISSUE

This dispute centers on the Settlement Agreement. The Settlement Agreement provides that it is governed by Michigan law, and contains sixteen numbered Sections. (A0183-84.) Of these sixteen Sections, three are particularly relevant to the present dispute.

First, Section 2 of the Settlement Agreement is the unrestricted license provision, which provides that:

> ***Relume***, and all of its officers, employees, assigns, and agents, including but not limited to Mr. Peter Hochstein and Mr. Denny Foy, hereby grants to ***Ecolux*** a paid-up, royalty-free, non-exclusive license under the ‘645 and ‘909 patents . . . and any reissues . . . thereof . . . .

(A0181.)

Second, Section 5 of the Settlement Agreement, the restricted covenant not to sue provision, provides that:

> ***Relume***, and all of its officers, employees, assigns, and agents, including but not limited to Mr. Peter Hochstein and Mr. Denny Foy, covenants, represents and warrants that it will not assert against Ecolux, its directors, officers, employees, agents, consultants, parent companies, subsidiaries, ***successor-in-interest, assigns***, customers, dealers, distributors, and each of them, any claim for infringement of [certain patents] by Ecolux’s LED signal products subject to discovery and/or accused by Relume of infringement in the Civil Action . . . .

(A0182.)

Finally, Section 14 of the Settlement Agreement provides that "[t]his Agreement shall inure to the benefit of, and be binding upon, the parties and their respective affiliates, successors and assigns." (A0184.)

SUMMARY OF THE ARGUMENT

The District Court erred in finding that Relume consented to the assignability of the license term through the generic language of Section 14, when that language omits any mention of assignability of that term. The Relume-Ecolux Settlement Agreement does not show any intent to authorize the assignment of the unrestricted license granted to Ecolux in Section 2. The license provision in Section 2 explicitly grants the unrestricted license only to Ecolux, and does not include any statement that the license was assignable or transferable to a successor of Ecolux. In contrast, Section 5 of the Settlement Agreement, which grants restricted rights to a finite pool of products in the form of a covenant not to sue provision, explicitly recites "successors and assigns" as recipients of those restricted rights. The Settlement Agreement thus expresses the parties' intent that the unrestricted license was granted solely to Ecolux. Section 14, which identifies and triggers standing for intended third-party beneficiaries, does not compel a conclusion otherwise. Because the Settlement Agreement only gave Ecolux an unrestricted license, GE did not become an unrestricted licensee of the '161 Patent when it acquired the assets of Ecolux. What GE did acquire through legal

ownership of the Settlement Agreement was standing under Michigan law to enforce the restricted covenant not to be sued on certain products.

The District Court relied only on a reading of the Settlement Agreement itself. RCT contends that if it cannot be concluded on that analysis that GE only obtained a restricted covenant not be sued, then at a minimum a material issue of fact exists as to the original intent of Relume and Ecolux whereby entry of summary judgment was inappropriate. For example, Ecolux's decision not to supply a promised legal opinion of full assignability in the period just after execution is powerful parol evidence of Ecolux's intent not to have bargained for full assignability.

ARGUMENT

I. STANDARD OF REVIEW

A District Court's grant of summary judgment is reviewed *de novo*. *Rembrandt Data Techs., LP v. AOL, LLC*, 641 F.3d 1331, 1336 (Fed. Cir. 2011). Contract interpretation is a question of law that is also reviewed de novo. *Id.*

II. THE RELUME-ECOLUX SETTLEMENT AGREEMENT DOES NOT AUTHORIZE THE TRANSFER OF AN UNRESTRICTED LICENSE TO THE '161 PATENT PREVIOUSLY HELD BY ECOLUX

It is a principle of federal common law that patent license rights are not assignable or transferable absent express consent. *See Rhone-Poulenc Agro, S.A. v. DeKalb Genetics Corp.*, 271 F.3d 1081, 1088 (Fed. Cir. 2001) ("[C]ourts generally

have acknowledged the need for a uniform national rule that patent licenses are personal and non-transferable in the absence of an agreement authorizing assignment . . . .") (vacated on other grounds); see also *In re CFLC, Inc.*, 89 F.3d 673 (9th Cir. 1996) ("Federal law holds a nonexclusive license to be personal and nonassignable . . . ."); *Unarco Indus., Inc. v. Kelley Co.*, 465 F.2d 1303, 1306 (Fed. Cir. 1972) ("The long standing federal rule of law with respect to the assignability of patent license agreements provides that these agreements are personal to the licensee and not assignable unless expressly made so in the agreement."). Allowing the free assignability of patent licenses would frustrate the purpose of granting exclusive rights to patent holders because "even if the patentee could control the number of licenses, he would lose the very important ability to control the identity of the licensees." *Rhone-Poulenc*, 271 F.3d at 1088.

In this case, it is undisputed that Relume provided authorization to transfer or assign the Settlement Agreement to a future unknown third party such as GE. But that does not mean that the unrestricted license right of Section 2 went with it, when the parties intended Section 5 to address that scenario. The District Court's holding to the contrary renders completely superfluous the carefully crafted "successors and assigns" language of Section 5, negating the benefit of the bargain Relume sought and received when putting "successors and assigns" rights into one type of rights-grant, but withholding it from another. Put another way, the District

Court's reading inequitably permits free assignment of the unrestricted license right of Section 2 to a global giant like GE, when the measure of consideration paid by Ecolux for that right was tailored specifically to its much smaller size.

The Settlement Agreement is governed by Michigan law, under which "[t]he primary goal in the construction or interpretation of any contract is to honor the intent of the parties." *Klapp v. United. Ins. Group Agency, Inc.*, 663 N.W.2d 447, 456 (Mich. 2003). Michigan law yields to the federal implied-in-law term mentioned above, that a patentee must express consent for license rights to be assignable. The analysis leading to reversal is simple. The District Court relied on Section 14 as overcoming the default term and supplying the patentee's consent. But the words are not there. Neither the District Court nor GE ever supplied any court decision or precedent holding that a generic "successors and assigns" clause that fails to use words of consent mentioning license rights might qualify to overcome this implied-in-law term of prohibition. The default term stands. Therefore, even before plumbing the intent of the parties, the District Court may be reversed for legal error in finding words of consent in a term that does not have them.

This conclusion only becomes more obvious in view of the clear evidence of the parties' intent. Looking at the Settlement Agreement as a whole, the only reasonable interpretation is that the parties did not intend for the unrestricted

license granted to Ecolux to be assignable. *See Perry v. Sied*, 611 N.W.2d 516, 520 (Mich. 2000) (recognizing the "well-established principle that contracts are to be construed in their entirety").

The fact most pertinent to this dispute is that the license provision of the Settlement Agreement in Section 2 unequivocally lists Ecolux as the sole recipient of the unrestricted, non-exclusive license. (A0181, ¶ 2.) ("Relume . . . hereby grants to Ecolux a paid-up, royalty-free, non-exclusive license . . . .") It is additionally indisputable that the Settlement Agreement does not explicitly state that Ecolux can assign this unrestricted license. (A0180-84.) Clearly, Relume and Ecolux knew how to provide for the transferability or assignability of rights under the '161 Patent as found in Section 5 in the form of a restricted covenant not to be sued.

Board of Regents of the Univ. of Nebraska v. BASF Corp., 2007 U.S. Dist. LEXIS 82497, at *2, **36-44 (D. Neb. Nov. 6, 2007), is informative. In that case, Sandoz Argo held a non-exclusive patent license from the University of Nebraska. Sandoz Argo purported to assign its non-exclusive license to BASF under an Asset Purchase Agreement that conveyed the entire business unit related to that license. Even though Sandoz Argo had "sublicense" rights under the agreement, the court held that it had no power to assign the license itself. It based its holding on the

personal nature of patent licenses and the lack of language permitting outright assignment. *Id.* The same principles apply here.

The District Court, however, found that Section 14 of the Settlement Agreement renders the unrestricted license of Section 2 to Ecolux assignable. (A0005-6.) Section 14 provides that the "Agreement shall inure to the benefit of, and be binding upon, the parties and their respective affiliates, successors and assigns." (A0184.) The District Court found that Section 14 applies to the Settlement Agreement as a whole, and because there is no language "carving out" the Section 2 unrestricted license provision, the unrestricted license granted to Ecolux must be assignable. (A0005-6.) This logic is backwards and flawed. It fails to recognize that the federal law default term of prohibition must stand unless there is a "carving in" of consent to the assignability of the license term. The onus was on GE to show such a thing, and it could not. The District Court's analysis also does not defeat the plain language of the Agreement under which the unrestricted license is granted solely to Ecolux. Put another way, why would Relume and Ecolux have gone to the trouble of providing for the transfer of a restricted covenant not to be sued if an unrestricted license was transferable?

Whether Section 14 applies to the Settlement Agreement as a whole has no bearing on whether the unrestricted license to Ecolux was transferable with the Settlement Agreement. Simply because Section 14 applies to the entire Settlement

Agreement, it does not follow that Section 14 alters the nature of the rights explicitly spelled out within the Settlement Agreement. Section 14 names the intended third-party beneficiaries of the entire Settlement Agreement. *See Dynamic Construction Co. v. Barton Marlow Co.*, 543 N.W.2d 31, 33 (Mich. App. 1995) ("Third party beneficiary status requires an express promise to act to the benefit of the third party; where no such promise exists, that third party cannot maintain an action for breach of the contract."). But these third party beneficiaries must accept the Settlement Agreement as it is written, in which the unrestricted license is explicitly granted only to Ecolux while assignee-beneficiaries enjoy a more narrow covenant not to be sued on a limited pool of products.

Moreover, whether the Settlement Agreement as a whole is transferrable also misses the point. Regardless of the transferability of the Settlement Agreement itself, the Settlement Agreement indicates the parties' intent that the unrestricted license granted therein is only to Ecolux. The District Court criticized RCT's interpretation for requiring a "paragraph-by-paragraph analysis of the Agreement in order to determine assignability." (A0007.) Such criticism is off the mark, however, because there is no other way to determine if a given term is assignable other than by analyzing what it says. It is entirely proper to look beyond Section 14 to determine whether a particular right - particularly a presumptively non-assignable right - was intended to be assignable. *See Perry v. Sied*, 611 N.W.2d at

520 (recognizing the "well-established principle that contracts are to be construed in their entirety"); *Paige v. Faure*, 229 N.Y. 114, 118-119 (N.Y. 1920) (finding non-assignability despite language that the "agreement shall bind and benefit the respective successors and assigns of the parties hereto" because "intention of the parties must be ascertained, not from one provision, but from the entire instrument."). Whatever Section 14, and its use of the word "assigns," may indicate about the parties' intentions as to the assignability of the Settlement Agreement itself, Section 14 does not in any way suggest that the parties intended that every individual term or right originally granted within the Settlement Agreement be assignable.

Indeed, an examination of the entire Agreement shows that the parties did not intend for every right granted therein to be assignable. This is evidenced by the fact that the parties explicitly included references to "successors" and "assigns" in certain provisions throughout the Agreement, while omitting it from others. Most notably, in Section 5 of the Agreement, Relume granted a covenant not to sue, but only with respect to certain products:

> ***Relume***, and all of its officers, employees, ***assigns***, and agents, including but not limited to Mr. Peter Hochstein and Mr. Denny Foy, covenants, represents and warrants that it will not assert against ***Ecolux***, its directors, officers, employees, agents, consultants, parent companies, subsidiaries, ***successor-in-interest, assigns***, customers, dealers, distributors, and each of them, any claim for infringement of [certain patents] by Ecolux's LED signal products subject to

> discovery and/or accused by Relume of infringement in the Civil Action . . . .

(A0182.) Unlike the Section 2 unrestricted license provision, Relume explicitly granted this narrower right, limited to certain products, to Ecolux's "successors and assigns." Similarly, in Section 8 of the Settlement Agreement, the parties provided that "each party hereto hereby releases the other party hereto and its . . . successors-in-interest, assigns . . . ." (A0183.) The parties thus explicitly referred to "successors and assigns" when they deemed it appropriate. The fact that the parties did not do so in Section 2 can only be indicative of the fact that the unrestricted license to Ecolux was not intended to be assignable.

Contrary to the findings of the District Court, other aspects of the Settlement Agreement do not compel the conclusion that the parties intended every right granted within the Settlement Agreement to be assignable. The District Court points to Section 7 of the Agreement which provides that "Relume's original amended complaint and any complaint reinstated on remand from any appeal from the Judgment by Relume shall be dismissed with prejudice with respect to Ecolux." (A0182.) The District Court found this provision to suggest that the parties only used the word "Ecolux," even when they intended a promise to run to Ecolux's "successors and assigns." (A0007.) According to the District Court, "[i]t is not clear why RCT and Ecolux would have agreed that in circumstances in which Ecolux itself is immune from suit, Ecolux's successor or assign - which may be

undertaking precisely the same infringing conduct as Ecolux had - would remain subject to suit." (Id.) The District Court's analysis is flawed, because any "complaint reinstated on remand from any appeal from the Judgment" would not have named Ecolux's successors and assigns to the extent they were involved in "precisely the same infringing conduct as Ecolux had [been engaging in]" since they expressly would have had the benefit of Section 5 covenant not to be sued. (A0182; A0007.) Section 7 is meaningful, consistent and logical when adopting RCT's interpretation, whereby the word "Ecolux" does not automatically include its successors and assigns. Of course, if Ecolux's successors and assigns went outside the restricted covenant in this hypothetical scenario (one that never played out), they could be sued - as GE has been - and Section 7 would bear no relevance to them.

The District Court's references to Sections 9-11 of the Settlement Agreement are likewise misguided. The District Court pointed to the various covenants and representations recited in Sections 9-11 of the Settlement Agreement seemingly as evidence that the parties did not consistently recite "successors and assigns," even when they intended a right to flow to "successors and assigns." (A0007.) Sections 9-11, however, do not include language granting ***rights*** to Ecolux or Relume. Rather, these provisions recite covenants and representations by the parties. (A0183.) The plain language of Section 14, "[t]his

Agreement shall . . . be binding upon, the parties and their respective affiliates, successors, and assigns," binds the parties' successors and affiliates to these covenants and representations. (A0184.) Thus, contrary to the District Court's characterizations, Relume does not dispute that these provisions extend to the parties' successors and assigns by operation of Section 14. Covenants and representations can be "binding upon" particular entities, and unlike the federal bar on unilateral assignability of patent license rights, no default implied-in-law term protects a transferee from being so "bound." The District Court was wrong to hold Sections 9-11 up as reflecting either rights-grant terms, or some kind of inconsistency in RCT's argument.

The only case law on point cited by either party supports RCT. Precedent holds that mere inclusion of a generic "successors and assigns" clause does not render an otherwise non-assignable license assignable. *Hy King Assocs., Inc. v. Versatech Mg. Indus., Inc.*, 826 F. Supp. 231 (E.D. Mich. 1993), is instructive on this point. There, the court addressed an agreement with the following language:

> 5. . . . Agent [C. Hyatt King] shall not assign or transfer this Agreement or any rights or obligations hereunder except with the prior written consent of Principal [the Defendant]. Any attempt at assignment without such written consent shall be deemed null and void and of no effect.
>
> [5. G] This agreement shall bind and inure to the benefit of the parties hereto or their assigns, but shall be [assigned] by the agent only with the consent of the principal.

Id. at 238-39. Thus, in *Hy King*, the court confronted an agreement with a "successors and assigns" clause, but with an express prohibition on assignability absent consent. The only difference here is that the prohibition is implied-in-law, not express, a distinction without a difference. The plaintiff in *Hy King* was the purported assignee of Agent C. Hyatt King, and sought a ruling that the assignment was valid. The court concluded that the condition precedent (*i.e.*, consent) had not occurred, and held that no assignment had any effect. *Id.* at 239. The court went on to add an independent basis for its holding - that in Michigan, a contract that "is personal in nature [is] not assignable by the agent without the principal's consent." *Id.* (citing *Detroit Postage Stamp Serv. Co. v. Schermack*, 179 Mich. 266 (1914)). This is analogous to the federal common law restriction on assignability of patent licenses. For these two independent reasons (express prohibition language, and an implied-in-law prohibition), the "successors and assigns" clause did not permit assignability because express and (independently) implied legal requirements for consent had not been met before the purported assignment.

The unrestricted license provision of the Settlement Agreement is clear - only Ecolux received it. This conclusion is reinforced by the explicit grant of other rights within the Agreement to "successors and assigns," such as in the restricted covenant not to sue provision. Nothing within Section 14 compels the conclusion that, despite every other aspect of the Agreement, the parties actually intended for

the unrestricted license to Ecolux to be assignable. And on summary judgment, the conclusion is inescapable that at a minimum, a material issue of fact exists, bolstered by Ecolux's reticence to ratify full assignability when pressed by GELcore, LLC in 2000, and despite a binding obligation to do so.

CONCLUSION AND STATEMENT OF RELIEF SOUGHT

The Relume-Ecolux Settlement Agreement does not evidence the transferability of the unrestricted license to Ecolux granted therein. As such, GE cannot have become an unrestricted licensee of the '161 Patent upon its acquisition of the Ecolux assets. RCT, therefore, respectfully requests that the Court reverse the District Court's grant of summary judgment and remand this matter to the District Court for further proceedings.

Dated: March 31, 2014

Respectfully submitted,

/s/ Timothy J. Haller

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PROOF OF SERVICE

The undersigned hereby certifies that on March 31, 2014 I caused the foregoing **BRIEF OF PLAINTIFFS-APPELLANTS RELUME CORPORATION TRUST, ET AL.** to be electronically filed through the CM/ECF system, which will send a notice of electronic filing to counsel for all parties to the action who are registered in the CM/ECF system. Copies of the above-mention document have also been served by e-mail to the following:

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Dated: March 31, 2014

/s/ Timothy J. Haller
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Relume Corporation Trust, et al.

CERTIFICATE OF COMPLIANCE

The undersigned hereby certifies that this brief complies with the type-volume limitation of Federal Rule of Appellate Procedure 32(a)(7)(B). The brief contains 4,057 words, excluding the parts of the brief exempted by Federal Rule of Appellate Procedure 32(a)(7)(B)(iii) and Federal Circuit Rule 32(b).

This brief complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type style requirements of Federal Rule of Appellate Procedure 32(a)(6). The brief has been prepared using Microsoft Word 2010 in Times New Roman, a proportionally spaced typeface, and 14-point size font.

Dated: March 31, 2014

/s/ Timothy J. Haller
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Attorney for Plaintiffs-Appellants,
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ADDENDUM

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ADDENDUM 1

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

RELUME CORPORATION TRUST, and DENNY FOY, SHAWN GRADY and MARIE HOCHSTEIN, TRUSTEES,	:	
Plaintiffs,	:	
	:	C.A. No. 12-871-LPS
v.	:	
GE LIGHTING SOLUTIONS, LLC,	:	UNSEALED ON JANUARY 7, 2014
Defendant.	:	

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MEMORANDUM OPINION

December 30, 2013
Wilmington, Delaware

STARK, U.S. District Judge:

Pending before the Court is Defendant GE Lighting Solutions, LLC's ("GE" or "Defendant") Motion for Summary Judgment on Plaintiffs' Sole Claim – Patent Infringement. (D.I. 54) For the reasons set forth below, the Court will grant the motion.

I. BACKGROUND

On July 12, 2012, Plaintiffs Relume Corporation Trust and Denny Foy, Shawn Grady, and Marie Hochstein, as Trustees of the Relume Corporation Trust (collectively, "RCT" or "Plaintiffs") filed suit against GE alleging infringement of United States Reissued Patent No. RE 42,161 (the "'161 Reissue"). (D.I. 1) The '161 Reissue is a reissue of United States Patent No. 5,661,645 (the "'645 patent"), and relates generally to power supply and circuit compatibility for use with light-emitting diodes.

On May 9, 2013, GE moved for summary judgment. (D.I. 54) The parties completed briefing on the motion on June 3, 2013. (D.I. 55, 60, 63) The Court heard oral argument on the pending motion, as well as on claim construction, on August 23, 2013. (*See* Transcript of Aug. 23, 2013 hearing (hereinafter "Tr."))

II. LEGAL STANDARDS

"The court shall grant summary judgment if the movant shows that there is no genuine dispute as to any material fact and the movant is entitled to judgment as a matter of law." Fed. R. Civ. P. 56(a). The moving party bears the burden of demonstrating the absence of a genuine issue of material fact. *See Matsushita Elec. Indus. Co., Ltd. v. Zenith Radio Corp.*, 475 U.S. 574, 585-86 (1986). An assertion that a fact cannot be – or, alternatively, is – genuinely disputed must be supported either by citing to "particular parts of materials in the record, including depositions,

documents, electronically stored information, affidavits or declarations, stipulations (including those made for purposes of the motion only), admissions, interrogatory answers, or other materials," or by "showing that the materials cited do not establish the absence or presence of a genuine dispute, or that an adverse party cannot produce admissible evidence to support the fact." Fed. R. Civ. P. 56(c)(1)(A) & (B). If the moving party carries its burden, the nonmovant must then "come forward with specific facts showing that there is a genuine issue for trial." *Matsushita*, 475 U.S. at 587 (internal quotation marks omitted). The Court will "draw all reasonable inferences in favor of the nonmoving party, and it may not make credibility determinations or weigh the evidence." *Reeves v. Sanderson Plumbing Prods., Inc.*, 530 U.S. 133, 150 (2000).

To defeat a motion for summary judgment, the nonmoving party must "do more than simply show that there is some metaphysical doubt as to the material facts." *Matsushita*, 475 U.S. at 586; *see also Podobnik v. U.S. Postal Serv.*, 409 F.3d 584, 594 (3d Cir. 2005) (stating party opposing summary judgment "must present more than just bare assertions, conclusory allegations or suspicions to show the existence of a genuine issue") (internal quotation marks omitted). However, the "mere existence of some alleged factual dispute between the parties will not defeat an otherwise properly supported motion for summary judgment;" and a factual dispute is genuine only where "the evidence is such that a reasonable jury could return a verdict for the nonmoving party." *Anderson v. Liberty Lobby, Inc.*, 477 U.S. 242, 247-48 (1986). "If the evidence is merely colorable, or is not significantly probative, summary judgment may be granted." *Id.* at 249-50 (internal citations omitted); *see also Celotex Corp. v. Catrett*, 477 U.S. 317, 322 (1986) (stating entry of summary judgment is mandated "against a party who fails to

make a showing sufficient to establish the existence of an element essential to that party's case, and on which that party will bear the burden of proof at trial"). Thus, the "mere existence of a scintilla of evidence" in support of the nonmoving party's position is insufficient to defeat a motion for summary judgment; there must be "evidence on which the jury could reasonably find" for the nonmoving party. *Anderson*, 477 U.S. at 252.

III. DISCUSSION

The issue before the Court is whether GE obtained a license to the '161 Reissue through its 2000 acquisition of Ecolux, Inc. ("Ecolux"). Previously, in December 1999, RCT and Ecolux resolved a prior patent infringement lawsuit by entering into a Settlement Agreement (the "Agreement"). (D.I. 56 Ex. B) Three provisions of the Agreement are particularly pertinent here.

First, Section 2 of the Agreement provides a license:

> ***Relume***, and all of its officers, employees, ***assigns***, and agents, including but not limited to Mr. Peter Hochstein and Mr. Denny Foy, hereby grants to ***Ecolux*** a paid-up, royalty-free, non-exclusive license under the '645 and '909 patents . . . and any reissues . . . thereof . . . .

(Emphasis added)

Next, Section 5 provides a covenant not to assert certain patents:

> ***Relume***, and all of its officers, employees, ***assigns***, and agents, including but not limited to Mr. Peter Hochstein and Mr. Denny Foy, covenants, represents and warrants that it will not assert against ***Ecolux***, its directors, officers, employees, agents, consultants, parent companies, subsidiaries, ***successor-in-interest, assigns***, customers, dealers, distributors, and each of them, any claim for infringement of its . . . '645 and '909 patents [and other Relume patents, with respect to certain Ecolux LED signal products] . . . .

(Emphasis added)

Finally, Section 14, states:

> This Agreement shall inure to the benefit of, and be binding upon, the parties and their respective affiliates, ***successors and assigns.***

(Emphasis added)

There is no dispute that Ecolux transferred the Agreement to GE as part of GE's acquisition of Ecolux. (*Id.* Ex. C at § 1.1) For purposes of the motion, there is also no dispute that GE is a successor of Ecolux and that the Agreement applies to the '161 Reissue patent-in-suit. (*See* DI 60 at 2 n.1) The parties agree that the Agreement is governed by Michigan law, and that also applicable is the federal common law principle that patent licenses are not generally assignable without language expressly permitting assignment. (*See* D.I. 55 at 6; D.I. 60 at 2; *see also In re CFLC, Inc.*, 89 F.3d 673, 679 (9th Cir. 1996) ("It is well settled that a non-exclusive licensee of a patent has only a personal and not a property interest in the patent and that this personal right cannot be assigned unless the patent owner authorizes the assignment or the license itself permits assignment.") (internal quotation marks omitted)) The parties further agree that Section 14 of the Agreement permits the transfer of the Settlement Agreement generally. (Tr. at 10-11, 18)

What is in dispute is the overall applicability of Section 14. GE contends that Section 14 applies to the entirety of the Agreement, permitting the assignment by Ecolux to GE of the Section 2 license to the '161 Reissue through execution of the acquisition. RCT contends, by contrast, that Section 14 is not so broad and only demonstrates the general transferability of the Agreement as a whole.

The Court concludes that Section 14's broad "successors and assigns" clause properly applies to the '161 Reissue license granted in Section 2. "[M]any other jurisdictions have concluded that similar ["successor and assigns"] provisions demonstrate that the parties contemplated and assented to future assignment." *Fransmart, LLC v. Freshii Dev., LLC*, 768 F. Supp. 2d 851, 861 (E.D. Va. 2011) (collecting cases). Here, Section 14 broadly, and without any express exclusion, provides that "***[t]his Agreement*** shall inure to the benefit of . . . ***successors and assigns***." (Emphasis added) Nothing in Section 14 ***excludes*** the rights granted in Section 2 from those rights that may be transferred to Ecolux's successors and assigns. Nor does any other provision in the Agreement provide for such exclusion. The Court agrees with GE that, "[w]hen considered within the context of the Agreement as a whole, it is clear that Section 14 was included to allow Ecolux's affiliates, successors, and assigns to benefit from all of the rights granted in the Agreement, including specifically, the license rights granted in Section 2." (D.I. 63 at 8) As the entirety of the Settlement Agreement is transferable, and nothing in that Agreement expressly excludes the license in Section 2 from the general transferability of the entire Agreement, the Court concludes that the license was transferable. *See Stenke v. Masland Dev. Co., Inc.*, 394 N.W.2d 418, 425 (Mich. Ct. App. 1986) ("Absent a contractual provision prohibiting assignment, an option . . . is assignable.").

Plaintiff's contrary interpretation of the Agreement emphasizes that Section 2, the license provision, does not contain "any language, of any form whatsoever, stating or suggesting that this particular license grant is 'assignable' or that it reaches 'successors.'" (D.I. 60 at 3) By contrast, RCT observes, Section 5, the covenant not to assert certain patents, expressly refers to Ecolux's successors and assigns. (*Id.*) To Plaintiff, then, Section 14 does not create any rights in Ecolux's

successors and assigns but, instead, "merely reflects that, to the extent successors and assigns have rights within the agreement (*e.g.*, Section 5), the Agreement inures to their benefit." (D.I. 60 at 4)

GE persuasively explains why RCT's approach to the Agreement is untenable. As GE observes, RCT's interpretation requires a paragraph-by-paragraph analysis of the Agreement in order to determine assignability; and, further, RCT requires that assignability is limited only to those portions of the Agreement that expressly reference not just Ecolux but ***also*** its successors and assigns. (*See generally* Tr. at 19) RCT's interpretation would lead to odd results, especially with respect to provisions that are not directly at issue here. For example, Section 7 provides that, should RCT's complaint be reinstated on remand from any appeal by RCT, such complaint "shall be dismissed with prejudice with respect to Ecolux." But Section 7 contains no reference to successors and assigns, meaning, in RCT's view, such complaint would not be dismissed with prejudice against an Ecolux successor or assign. It is not clear why RCT and Ecolux would have agreed that in circumstances in which Ecolux itself is immune from suit, Ecolux's successor or assign – which may be undertaking precisely the same infringing conduct as Ecolux had – would remain subject to suit. *See also* Agreement at ¶¶ 9-11 (additional provisions by which Ecolux, but ***not*** expressly its successors or assigns, covenants, represents, warrants, and/or promises, each of which is a provision which would not extend to Ecolux's successors or assigns under RCT's interpretation).

RCT faults GE's interpretation as "lead[ing] to some significant redundancies" (Tr. at 17), because GE would effectively read the word "Ecolux" everywhere in the Agreement to mean "Ecolux and its successors and its assigns." GE concedes that its reading of the Agreement has

this consequence. (*See* Tr. at 23-24) But neither party's interpretation avoids all redundancy, and the degree of redundancy resulting from GE's interpretation does not render RCT's contrary interpretation reasonable. RCT also references the contract interpretation doctrine of "*expressio unius*," which means that "inclusion by specific mention excludes what is not mentioned." *Hackel v. Macomb Cnty. Comm'n*, 826 N.W.2d 753, 762 (Mich. Ct. App. 2012) (internal quotation marks omitted). This doctrine does not apply to unambiguous contractual provisions like those at issue here. *See Grinnell Bros. v. Brown*, 171 N.W. 399, 400 (Mich. 1919).

RCT observes, correctly, that nowhere in the Agreement is it expressly stated that "the license to Ecolux is assignable." (Tr. at 16) Certainly, the Agreement could have been drafted more clearly on this point (and then this litigation likely could have been avoided). No explanation appears in the record as to why Ecolux's successors and assigns were not expressly called out in Section 2. Even so, the fact remains that the only reasonable interpretation of Section 14 is that the parties intended Ecolux's successors and assigns to enjoy all of the rights of Ecolux under the Agreement.

RCT points out that Section 2, the license provision, refers to Relume and ***its*** "assigns," making noteworthy the contrast on the other side of the transaction in that same Section 2, which references just "Ecolux." (*See* Tr. at 16) Again, this just illustrates that the Agreement is written with less than complete precision and clarity. It does not, however, render RCT's interpretation of the Agreement – as including a license that is not assignable – a reasonable interpretation.

The cases relied upon by RCT do not persuade the Court that summary judgment should be denied. *Hy King Assocs., Inc. v. Versatech Mfg. Indus., Inc.*, 826 F. Supp. 231, 239 (E.D. Mich. 1993), involved a "successors and assigns" provision that allowed assignment "only with

the consent of the principal," an unambiguous restriction on assignability not found in the Agreement here. *Stenograph Corp. v. Fulkerson*, 972 F.2d 726, 729 n.2 (7th Cir. 1992), considered whether a "successors and assigns" clause in a settlement agreement that was merely attached to – but not incorporated into – a patent license agreement (without a "successors and assigns" provision) made the license assignable; unlike here, where the very Agreement involved itself contains the "successors and assigns" provision at issue.

Hence, the Court concludes that the license granted by RCT to Ecolux did transfer to GE upon its acquisition of Ecolux. Accordingly, GE's motion for summary judgment will be granted.

IV. CONCLUSION

For the foregoing reasons, the Court will grant GE's Motion for Summary Judgment on Plaintiffs' Sole Claim – Patent Infringement (D.I. 54).

ADDENDUM 2

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

RELUME CORPORATION TRUST, and DENNY FOY, SHAWN GRADY and MARIE HOCHSTEIN, TRUSTEES,	:	
Plaintiffs,	:	
	:	C.A. No. 12-871-LPS
v.	:	
GE LIGHTING SOLUTIONS, LLC,	:	
Defendant.	:	

ORDER

At Wilmington, this 30th day of December, 2013:

For the reasons set forth in the Memorandum Opinion issued this same date,

IT IS HEREBY ORDERED that GE Lighting Solutions, LLC's Motion for Summary Judgment on Plaintiffs' Sole Claim – Patent Infringement (D.I. 54) is GRANTED.

IT IS FURTHER ORDERED that, no later than January 7, 2014, the parties shall submit a proposed redacted version of the Memorandum Opinion, which was issued under seal.

UNITED STATES DISTRICT JUDGE

ADDENDUM 3

Satterfield, Sandy L

From: ded_nefreply@ded.uscourts.gov
Sent: Thursday, January 23, 2014 10:08 AM
To: ded_ecf@ded.uscourts.gov
Subject: Activity in Case 1:12-cv-00871-LPS Relume Corporation Trust et al v. GE Lighting Solutions LLC Terminated Case

U.S. District Court

District of Delaware

Notice of Electronic Filing

The following transaction was entered on 1/23/2014 at 11:08 AM EST and filed on 1/23/2014
Case Name: Relume Corporation Trust et al v. GE Lighting Solutions LLC
Case Number: 1:12-cv-00871-LPS
Filer:
WARNING: CASE CLOSED on 01/23/2014
Document Number: No document attached

Docket Text:
CASE CLOSED (ntl)

1:12-cv-00871-LPS Notice has been electronically mailed to:

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1:12-cv-00871-LPS Filer will deliver document by other means to:

ADDENDUM 4

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

RELUME CORPORATION TRUST et. al, Plaintiffs, **v.** **GE LIGHTING SOLUTIONS, LLC, Defendant.**	**Case No. 1:12-cv-00871-LPS**

~~[PROPOSED]~~ ORDER ENTERING FINAL JUDGMENT

In light of this Court's prior grant of Defendant's motion for a summary judgment by virtue of a license (D.I. 84, 85) and a joint motion by the parties requesting a stipulated disposition of all remaining claims and counterclaims in this action, it is hereby Ordered that:

(1) A summary judgment of non-infringement as a result of the Court's finding that GE is licensed is entered in favor of Defendant against Plaintiffs.

(2) Defendant's counterclaims for declaratory judgments of: (a) patent invalidity; (b) non-infringement as a result of the accused devices lacking critical claim limitations; and (c) the existence of intervening rights are dismissed **without prejudice as moot**.

(3) Defendant's counterclaim claim for breach of contract is dismissed **without prejudice**.

The Court reserves its ability to award costs under Local Rule 54.1.

The Judgment entered by this order is intended to be a final judgment under Fed. R. Civ. P. 58.

IT IS SO ORDERED.

United States District Court Judge

ADDENDUM 5

US00RE42161E

(19) **United States**
(12) **Reissued Patent**
Hochstein

(10) **Patent Number: US RE42,161 E**
(45) **Date of Reissued Patent: Feb. 22, 2011**

(54) **POWER SUPPLY FOR LIGHT EMITTING DIODE ARRAY**

(75) Inventor: **Peter Anthony Hochstein**, Troy, MI (US)

(73) Assignee: **Relume Corporation**, Oxford, MI (US)

(21) Appl. No.: **09/382,702**

(22) Filed: **Aug. 24, 1999**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **5,661,645**
Issued: **Aug. 26, 1997**
Appl. No.: **08/673,200**
Filed: **Jun. 27, 1996**

(51) **Int. Cl.**
H02M 5/42 (2006.01)

(52) **U.S. Cl.** **363/89**

(58) **Field of Classification Search** 323/282, 323/284; 363/89, 80, 53, 127, 81, 126
See application file for complete search history.

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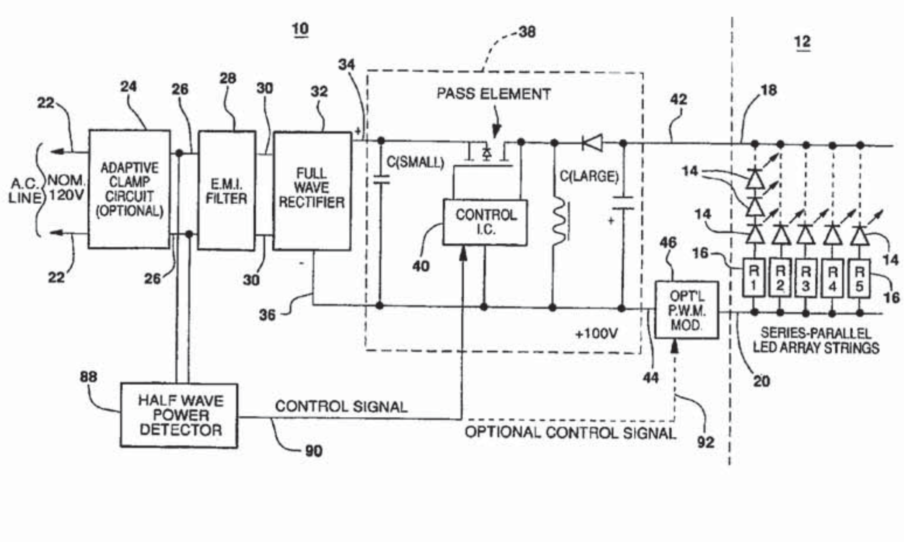
(Continued)

Primary Examiner—Adolf Berhane
(74) *Attorney, Agent, or Firm*—David M. Quinlan, P.C.

(57) **ABSTRACT**

An apparatus (**10**) for supplying regulated voltage d.c. electrical power to an LED array (**12**) includes a rectifier (**32**) responsive to a.c. power for generating rectified d.c. power and a power factor correcting and voltage regulating buck/boost switchmode converter (**38**) responsive to the rectified d.c. power for generating regulated voltage d.c. power to illuminate the LED array (**12**). A battery backup system (**62**) receives the a.c. power applied to the rectifier (**32**) for charging a rechargeable battery (**66**) and sensing an a.c. power failure. A switch-over relay (**82**) is connected between the battery backup system (**62**) and the rectifier. Upon sensing a failure of the a.c. power, the battery backup system (**62**) controls the switch-over relay (**82**) to connect the battery backup system (**62**) to the rectifier (**32**) to provide d.c. power to the switchmode converter (**38**) to illuminate the LED array (**12**). A half wave power detector (**88**) causes the apparatus (**10**) to reduce regulated d.c. power to dim the LED array (**12**).

16 Claims, 6 Drawing Sheets



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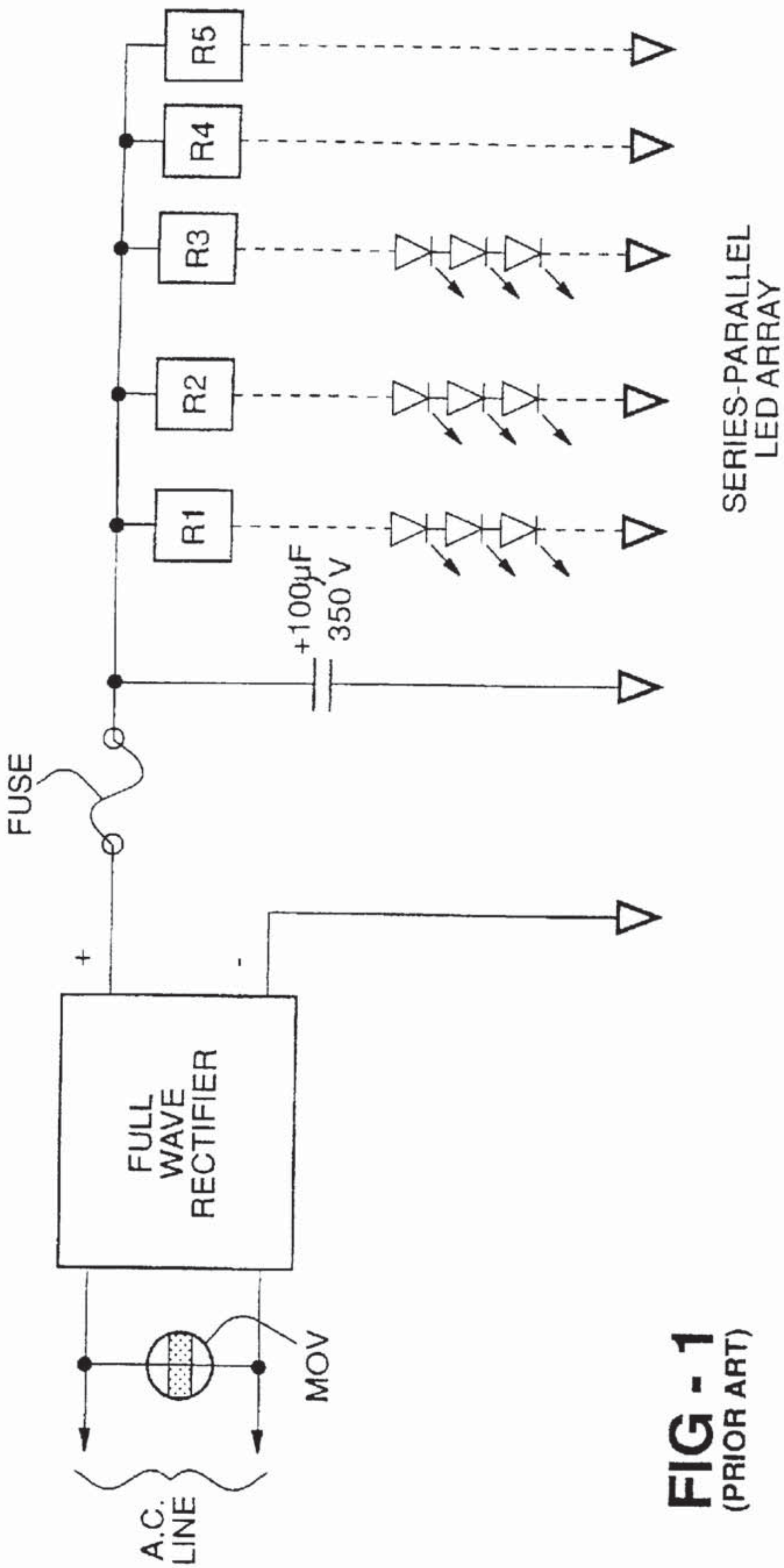


FIG - 1
(PRIOR ART)

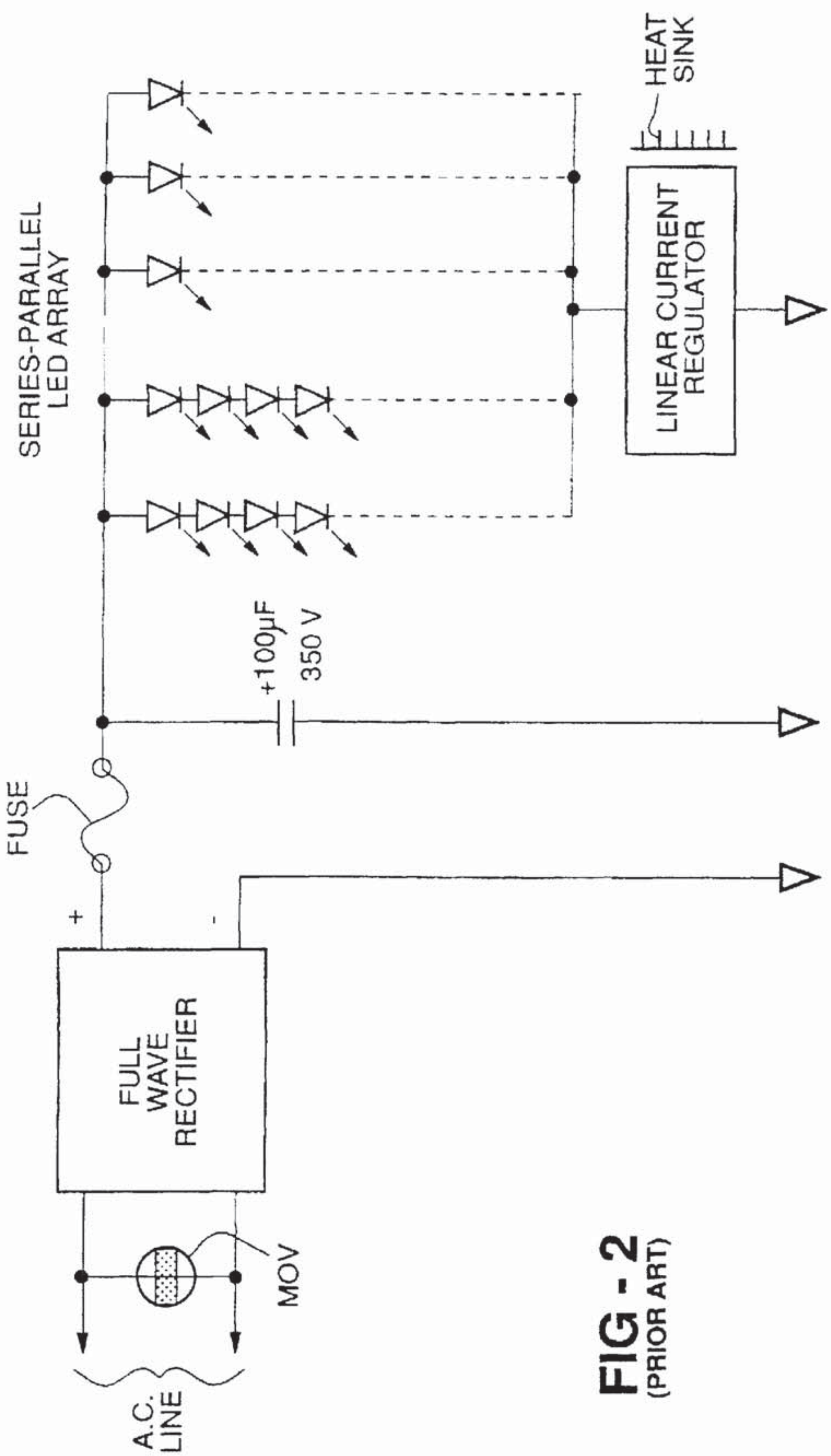


FIG - 2
(PRIOR ART)

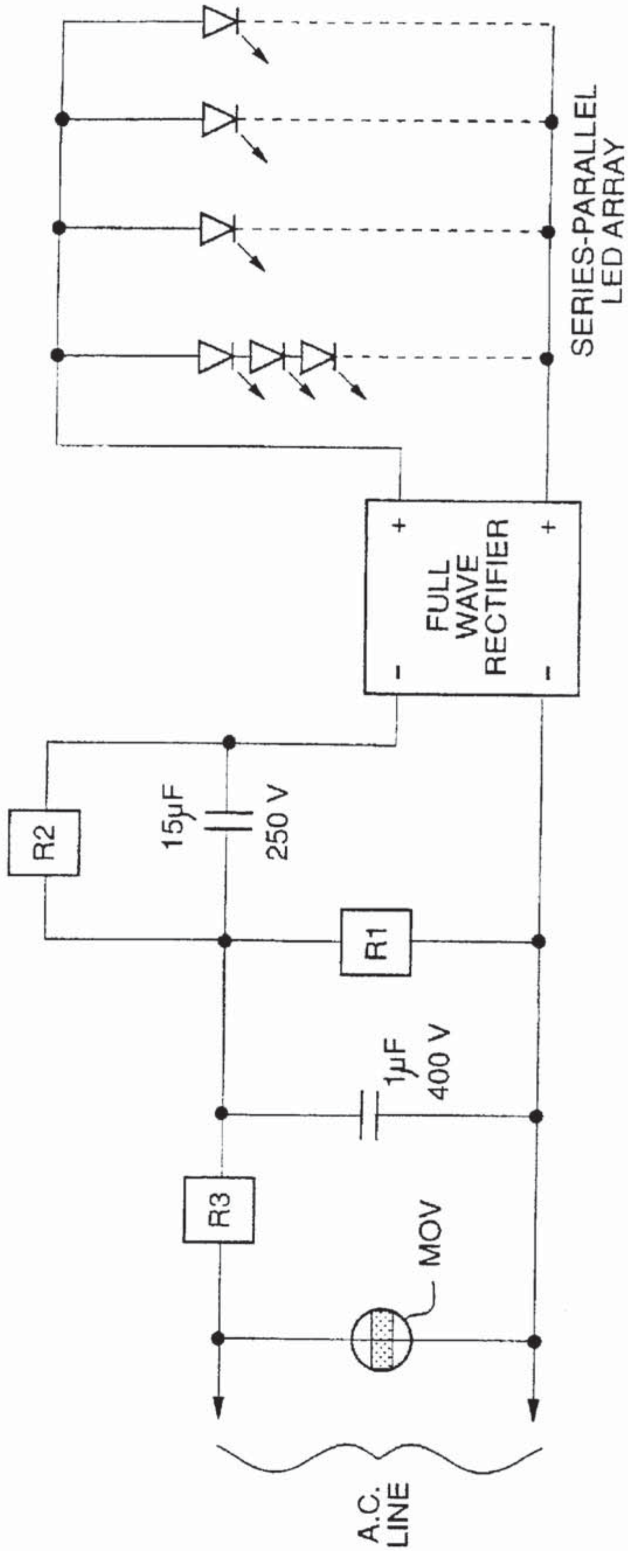


FIG - 3
(PRIOR ART)

FIG - 4

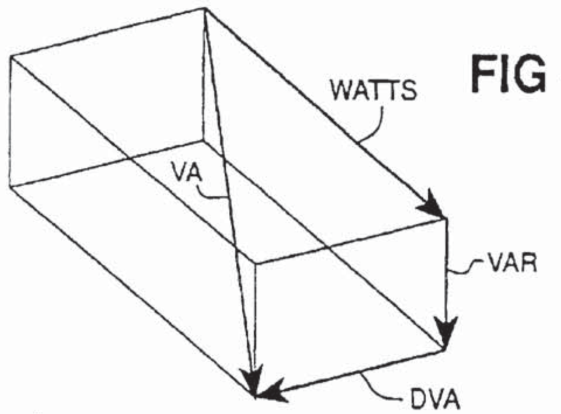


FIG - 6a
Amended

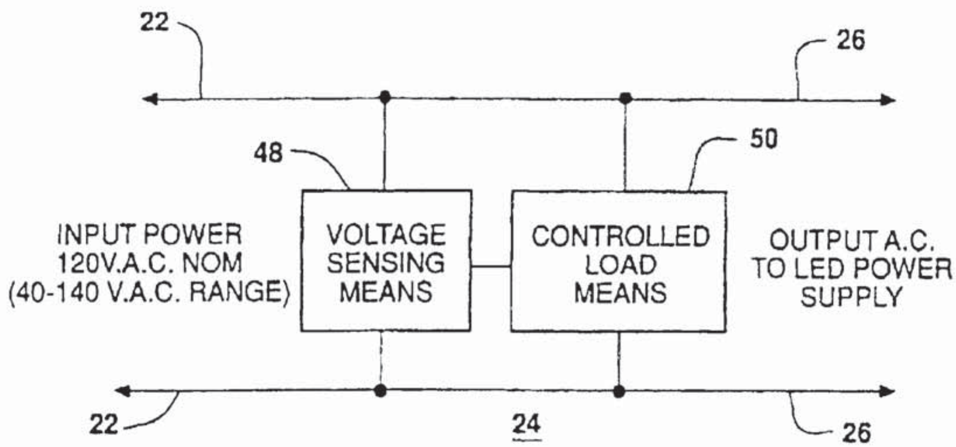
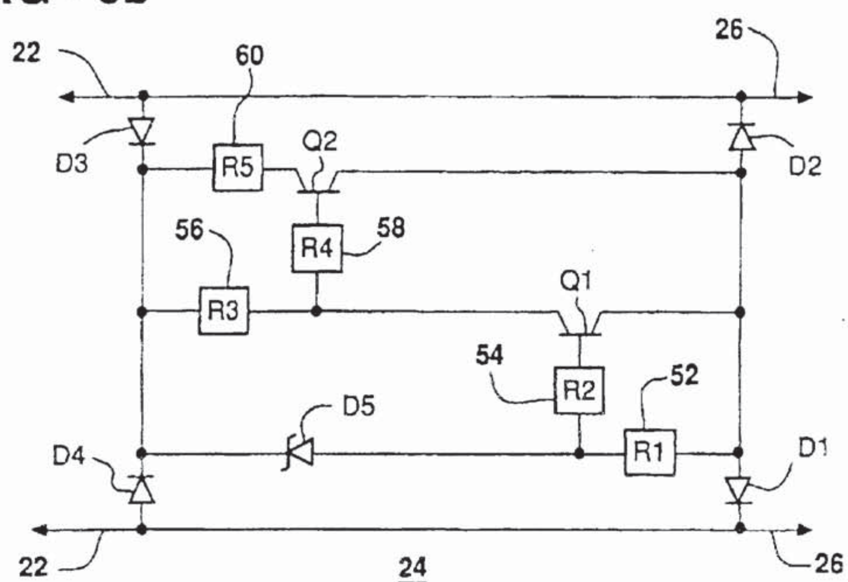
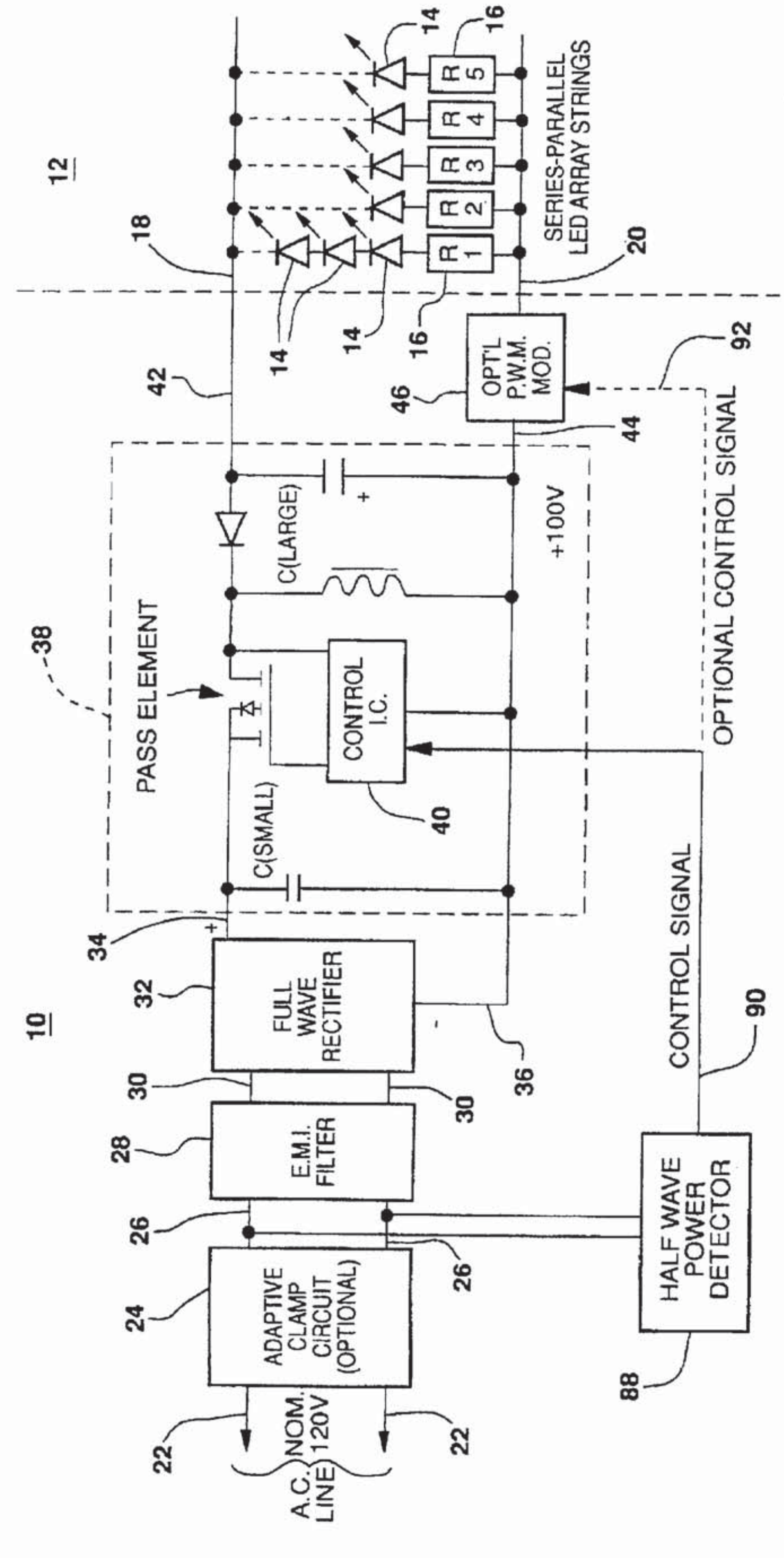


FIG - 6b





12
10
SERIES-PARALLEL LED ARRAY STRINGS
R 1
R 2
R 3
R 4
R 5
OPT'L P.W.M. MOD.
C(LARGE)
+100V
OPTIONAL CONTROL SIGNAL
PASS ELEMENT
CONTROL I.C.
C(SMALL)
FULL WAVE RECTIFIER
CONTROL SIGNAL
E.M.I. FILTER
HALF WAVE POWER DETECTOR
ADAPTIVE CLAMP CIRCUIT (OPTIONAL)
NOM. 120V
A.C. LINE
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
88
90
92

FIG - 5

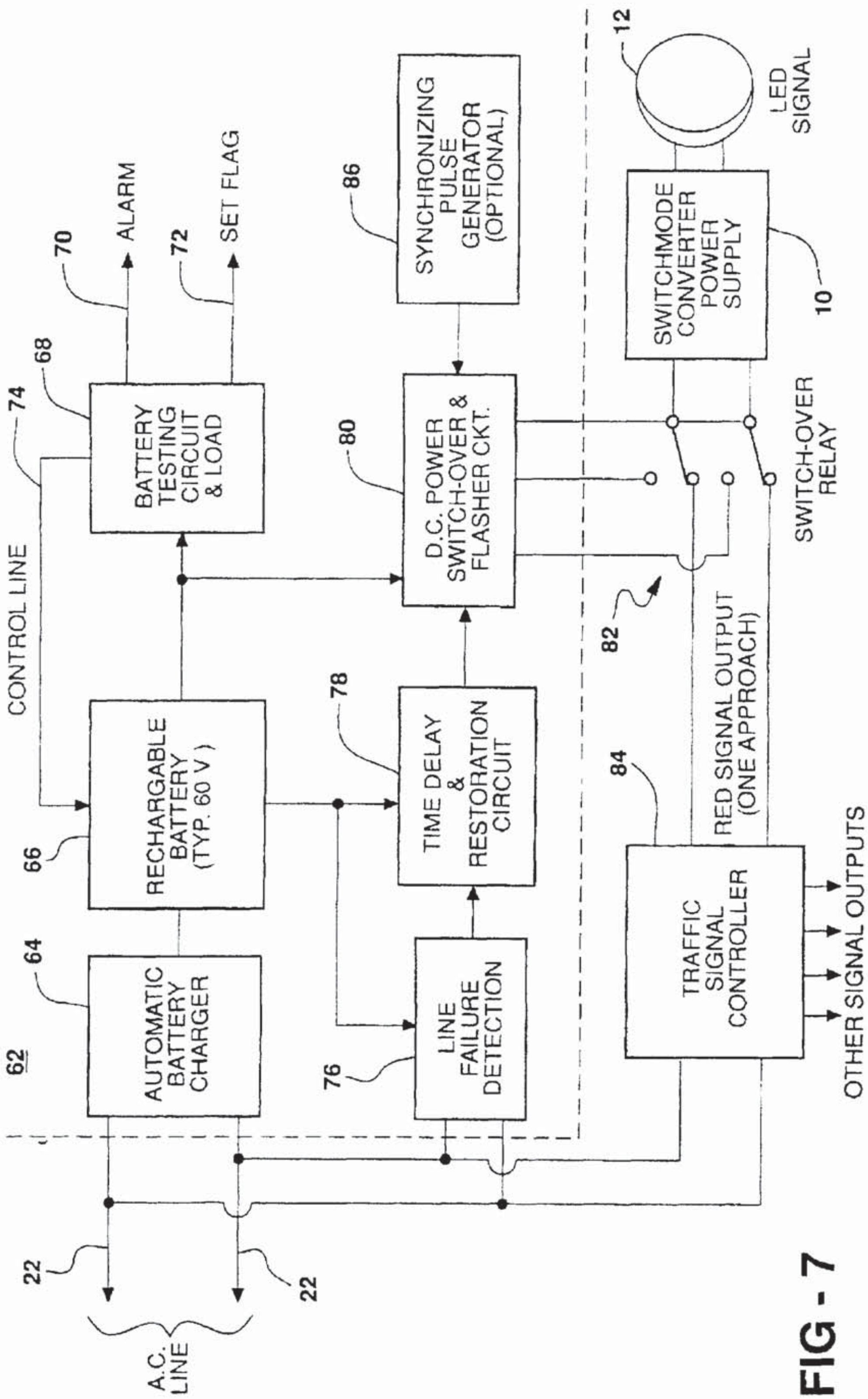

62
AUTOMATIC BATTERY CHARGER
64
RECHARGABLE BATTERY (TYP. 60 V)
66
CONTROL LINE
74
BATTERY TESTING CIRCUIT & LOAD
68
ALARM
70
SET FLAG
72
LINE FAILURE DETECTION
76
TIME DELAY & RESTORATION CIRCUIT
78
D.C. POWER SWITCH-OVER & FLASHER CKT.
80
SYNCHRONIZING PULSE GENERATOR (OPTIONAL)
86
82
TRAFFIC SIGNAL CONTROLLER
84
RED SIGNAL OUTPUT (ONE APPROACH)
OTHER SIGNAL OUTPUTS
SWITCH-OVER RELAY
SWITCHMODE CONVERTER POWER SUPPLY
10
LED SIGNAL
12
22
22
A.C. LINE

FIG - 7

POWER SUPPLY FOR LIGHT EMITTING DIODE ARRAY

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is the parent of a continuation reissue application filed Mar. 5, 2008, and accorded application Ser. No. 12/074,723.

BACKGROUND OF THE INVENTION

The present invention relates generally to an apparatus for generating power to a light emitting diode array and, in particular, to a power supply for operating light emitting diode array traffic signals.

Light emitting diode (LED) arrays are becoming more common in many applications as they are used to replace less efficient incandescent lamps. Status annunciators, message boards, liquid crystal display back lights and traffic signals are common applications for LED arrays. In most of these uses, electrical power is obtained from a.c. mains (120 v.a.c., 60 Hz) and some form of power supply converts the alternating line voltage to d.c., or pulsing d.c., for powering the plurality of LEDs.

LEDs typically exhibit forward voltage drops on the order of 1.2 to 2.0 volts when driven at average currents of 20 to 25 ma. For purposes of efficiency, the LEDs are usually connected in series so that a higher power supply voltage can be used to light an array of LEDs.

In many applications where a relatively large number of LEDs are necessary to deliver substantial light output, several series strings of LEDs with a ballasting resistor in each string are normally connected in parallel. As shown in the FIG. **1**., this traditional circuit arrangement provides some redundancy from single point LED failure, as any "open" LED will only extinguish its own series string leaving the other strings active. Since this relatively simple circuit does not provide any regulation, i.e. the light output varies with varying input voltage, it has been generally superseded by the regulated circuit shown in the FIG. **2**. The regulated circuit employs a linear current regulator instead of individual ballasting resistors to maintain a given current through the LED strings. The highly dissipative nature of such linear regulators makes such use questionable in heat sensitive apparatus such as LED signals however. Heat generated by the regulator could exacerbate the deterioration of the thermally sensitive LEDs.

A non dissipative. unregulated power supply for LED signals is shown in FIG. **3**, and uses a series capacitor as the current limiting element. Such highly reactive power supplies exhibit very poor power factors however, and may be disallowed by power utilities.

Several problems are associated with these prior art simple circuit topologies. The input current wave forms are generally badly distorted and the power factor is poor. Reasons for the poor power factor and high distortion relate to the discontinuous conduction of the diodes in the circuit feeding large capacitors. This phenomenon is well understood, and plagues many small off line power supplies. Until recently these concerns were essentially disregarded by the electrical power industry because the impact to the

power grid was relatively small. Of course, as larger numbers of these low power appliances are connected to the power grid, the effect is no longer inconsequential. In fact, many utilities are placing limits on permissible power factor and distortion behavior of electrical devices connected to their lines.

LED traffic signals are being retrofitted in place of incandescent lamps primarily because of the energy savings common to LED signals. For example, an 8 inch diameter incandescent signal might consume 67 watts and its LED equivalent 14 watts, or a 12 inch diameter incandescent signal would consume 150 watts while its LED replacement would consume only 28 watts. The dramatic energy savings translate into greatly reduced operating cost, which is an important criterion, as electrical power is becoming more expensive. Also, in many parts of the country, electrical generating capacity is at its limits, and new capacity cannot be added because of environmental concerns. This strong interest in LED signals as an important energy conservation resource is clouded however by the poor power factor performance of commercially available signals.

Power factor (p.f.) is well understood in the electrical engineering community as the ratio of real power to real power plus reactive power, or more conveniently. p.f.=cos θ where θ is the angle in electrical degrees of the current-voltage phase offset. That is, in many reactive loads powered by sinusoidal (alternating) current, the voltage and current may be out of phase.

The apparent power that has to be delivered to a given load in volt-amperes (VA) is, therefore equal to the true power consumption of the device in Watts divided by the power factor. For example, an appliance with an internal power consumption of 100 Watts that exhibited a power factor of 0.4, would require 100/0.4 or 250 VA of energy from the power line and utility generator. Taken separately, the many small electrical appliances that are widely used have only a moderate effect on generating capacity. However in aggregate, a large number of small devices can have a significant impact on the power grid.

By means of example, a medium size city (San Francisco) may have some 2000 signalized intersections with a total of 16,000 mixed 8 inch and 12 inch traffic signals. If the existing incandescent signals with an average power consumption of 100 watts are replaced with LED variants of 20 watt rating, a significant power saving should result. The 1600 kilowatt (kW) load imposed by the incandescent signals should be reduced to 320 kw by the LED retrofit devices. However, if the LED signals exhibit an actual power factor of 0.3, the resulting load to the power grid is 320 kW divided by 0.3 p.f. or 1067 kW. The energy savings is then only 533 kW, which is the net mount of power that the utility can convert to other uses. Clearly then, the need for power factors close to unity is apparent. Another factor that directly influences the amount of power (apparent VA) that needs to be delivered to a given load is the total harmonic distortion of the current waveform supplying the device. True power factor is adversely affected by current or voltage distortion, and the significance of this influence is only now being widely accepted. There is shown in the FIG. **4**, a traditional power factor vector diagram (which is normally two dimensional) which has been expanded to a three dimensional form to indicate the influence of distortion on the apparent power vector. The total power required vector VA (apparent power) is determined by the combination of the working power vector WATTS, the volt-amperes reactive vector VAR (non-working power) and the distortion volt-amperes vector DVA (non-working power).

Harmonic distortion or deviation from true sinusoidal wave forms not only gives rise to further wasted energy, but increases the electromagnetic interference potential of the load. Radiated and conducted interference is a concern because of the interference potential with other services (radio communications for example).

Harmonic distortion is becoming more prevalent in power supplies as these devices are converted from inefficient linear operation to far more efficient switchmode operation. A wide variety of circuit topologies are used in modern switching power supplies such as thyristor and triac phase control, or bipolar or field effect transistor switches. A consequence of these solid state approaches is increased harmonic distortion and poor power factor behavior. In order to mitigate these problems, several approaches to power factor and distortion control have been developed that operate with and use the efficiency of the switchmode power supply itself. That is, instead of correcting for power factor in a separate functional device (that is connected between the power supply and line), the power factor and distortion correcting function is part of the switchmode power supply. A number of manufacturers of integrated circuits (Linear Technology, Silicon General, Motorola and Unitrode for example) offer monolithic devices that perform the power factor and distortion control function. A review of this art is presented in Power Supply Cookbook by Marty Brown, 1994, Butterworth-Heinemann.

SUMMARY OF THE INVENTION

The present invention concerns an apparatus for supplying regulated voltage d.c. electrical power to an LED array. The apparatus includes a rectifier having an input and an output, the rectifier being responsive to a.c power at the input for generating rectified d.c. power at the output, a power factor correction converter having an input connected to the rectifier output and an output, the power factor correction converter being responsive to the rectified d.c. power at the power factor correction converter input for generating regulated voltage, d.c. power at the power factor correction converter output, and an LED array having an input connected to the power factor correction converter output for receiving the d.c. power to illuminate the LED array. The power factor correction converter can be a power factor correcting and voltage regulating buck/boost switchmode converter.

A primary object of the present invention is to provide a power factor correcting, (boost buck/boost or buck) switchmode converter to power a line operated LED signal.

Another object of the present invention is to use the inherent pulse modulating nature of a switchmode power supply to provide voltage regulation to an LED array.

The apparatus according to the present invention also includes an adaptive clamp circuit connected to the rectifier input for eliminating leakage current problems. The adaptive clamp circuit has an input adapted to be connected to a pair of a.c. power lines, a pair of clamp circuit output lines connected to the adaptive clamp circuit input, a voltage sensing means connected across the adaptive clamp circuit input, and a controlled load means connected across the clamp circuit output lines and to the voltage sensing means. The voltage sensing means is responsive to a magnitude of a.c. voltage at the adaptive clamp circuit input lower than a predetermined magnitude for turning on the controlled load means to connect a low impedance load in the controlled load means across the clamp circuit output lines and the voltage sensing means is responsive to a magnitude of the a.c. voltage at the adaptive clamp circuit input equal to or greater than the predetermined magnitude for turning off the controlled load means to disconnect the low impedance load from the clamp circuit output lines.

It is also an objective of the present invention to eliminate leakage current problems by providing an adaptive clamp circuit.

Another feature of the present invention is to provide an adaptive line loading means or clamp that switches itself in or out of the circuit as needed.

The apparatus according to the present invention further includes a battery backup system having an input for receiving a.c. power applied to the rectifier input and having an output at which d.c. power is generated, and a switch-over relay connected to the battery backup system output and to the rectifier input, the battery backup system being responsive to a failure of a.c. power at the battery backup system input for controlling the switch-over relay to connect the battery backup system output to the rectifier input to provide d.c. power to illuminate the LED array and being responsive to a.c. power at the battery backup system input for controlling the switch-over relay to disconnect the battery backup system output from the rectifier input.

Another object of the present invention is the use of a d.c. power supply (instead of the a.c. power line) as a power backup that is activated upon a.c. power line loss.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

FIG. **1** is a schematic diagram of a prior art unregulated power supply for LED signals;

FIG. **2** is a schematic diagram of a prior art linear current regulated power supply for LED signals;

FIG. **3** is a schematic diagram of a prior art reactively ballasted power supply for LED signals;

FIG. **4** is a three dimensional vector diagram of the total power required to operate an LED array;

FIG. **5** is a schematic diagram of a regulated voltage, switchmode power supply for LED signals in accordance with the present invention;

FIG. **6**a is a schematic block diagram of the adaptive clamp circuit shown in the FIG. **5**;

FIG. **6**b is a schematic diagram of the adaptive clamp circuit shown in the FIG. **6**a; and

FIG. **7** is a schematic block diagram of a battery backup system for LED signals according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As noted above, the elementary power supplies that are currently used for powering LED array signals do not meet current standards for efficiency, reliability and performance. The unregulated, resistively ballasted power supply shown in the FIG. **1** does not isolate the LEDs from line voltage variations, and exhibits a poor power factor because of the rectifier and large capacitor. The commercially produced current regulated LED power supply, which is shown in the FIG. **2**, does provide much better LED light intensity regulation with input voltage variation. However, the use of a linear, dissipative (heat producing) regulator presents problems. LEDs are thermally sensitive devices which degrade

quickly at elevated temperatures. Since most power supplies for LED signals are part of, or are attached to the LED array, heat rise from the linear regulator can be deleterious. Furthermore, the traditional rectifier-capacitor circuit does not produce a satisfactory power factor.

The use of capacitors as non-dissipative current limiters in a.c. circuits is well established, and is shown in the FIG. **3** as another example of a commercially available LED array signal power supply. Current and voltage wave forms are essentially out of phase in this type of circuit so that heat is not generated in the current limiting capacitor (15 μF). However, the power factor and distortion performance of this type of circuit is very poor (P.F.≈0.3).

There is shown in the FIG. **5**, a regulated voltage, switchmode power supply **10** according to the present invention connected to an LED array **12**. The LED array **12** includes a plurality of strings of series connected LEDs **14** with a ballasting resistor **16** (R**1**, R**2**, R**3**, R**4**, R**5**, . . .) connected in each string. The strings are connected in parallel between a first input line **18** and a second input line **20** of the LED array **12**.

The power supply **10** has a pair of power input lines **22** for connection to a source (not shown) of a.c. power such as main power lines at a nominal 120 volts a.c. An input of an adaptive clamp circuit **24** can be connected to the lines **22** as an option. A problem peculiar to signals that are switched by means of solid state relays is the leakage current that can flow through the load when the solid state switch or relay is "OFF". This phenomenon is common to triac and thyristor switches that are commonly employed in traffic signal controllers. While not apparent when incandescent signals are employed (because they are low impedance loads), the problems surface when relatively low power loads (such as LEDs) are connected to these same controllers. Typically, other safety devices used in traffic signal controllers such as conflict monitors must be "tricked" to reduce this leakage current. Commonly, a large capacitor is placed across the a.c. input leads to the LED load, in order to absorb the leakage current reactively. Of course, such provisions only aggravate the power factor problems.

An output of the adaptive clamp circuit **24** is connected by a pair of clamp circuit output lines **26** to an input of an electromagnetic interference (E.M.I.) filter **28**. The E.M.I. filter **28** keeps conducted interference from feeding back into the power lines where it might cause problems to other circuitry on the line. An output of the filter **28** is connected by a pair of filter output lines **30** to an input of a rectifier means **32** which converts the incoming a.c. power to a pulsing d.c. power generated on a positive polarity rectifier output line **34** and a negative polarity rectifier output line **36**. Although the rectifier means is shown as a full wave diode bridge rectifier, any type of rectifier can be used. The lines **34** and **36** are connected to an input of a power factor correction, buck/boost converter **38**. The converter **38** includes a power factor correction (P.F.C.) integrated circuit (I.C.) controller **40**, which is a commercial device available from many sources and functions by allowing current to charge a storage capacitor C (LARGE) only in phase with the rectified a.c. voltage thereby assuring a power factor close to unity. The control I.C. **40** also provides voltage regulation in the switchmode buck/boost converter by monitoring the output voltage and adjusting the high frequency on-off switching period of the pass element commensurately. Although a buck/boost converter is diagrammed, buck or boost topologies are also possible. Voltage output and current-mode control techniques are the primary differences in the various geometries, but these details are incidental to the functionality of the circuit.

A positive polarity output of the converter **38** is connected by a positive polarity converter output line **42** to the first input line **18** of the LED array **12**. A negative polarity output of the converter **38** is connected by a negative polarity convener output line **44** to the second input line **20** of the LED array **12** through an optional pulse width modulated (P.W.M.) modulator **46**.

The output voltage from the P.F.C. switch mode converter **38** is either fed directly to the LED array **12**, or alternatively through the P.W.M. modulator **46**. Such pulse modulation has been shown to be advantageous in certain LED signal applications. The functions of the switchmode P.F.C. converter **38** as the off line power supply are the same irrespective of the load. The obvious advantage of using a switching, voltage regulated power supply is efficiency. Line isolation, which is generally not provided by this transformerless design, is generally unnecessary for insulated LED signals, but a high frequency transformer could be incorporated. The intrinsic power factor correction provided by using the switchmode converter **38** in conjunction with the P.F.C. integrated circuit controller **40** is not only cost effective, but allows d.c. backup power to be used in case of line failure.

A primary aspect of the present invention is the use of a power factor correcting, (boost, buck/boost or buck) switchmode converter to power a line operated LED array signal **12**. Another function of the present invention is to use the inherent pulse modulating nature of the switchmode power supply to provide voltage regulation to the LED array signal **12**. Instead of using dissipative (heat producing) linear regulators for either voltage or current (to accommodate line voltage variations), the power factor and distortion controlling switchmode power supply **10** is used as an efficient voltage regulator. That is, the LED array **12**, consisting of a large number of series-parallel connected LED devices **14**, can be kept at essentially constant luminosity over a substantial range of input voltages. In actual practice, the output of such LED array signals has been kept within ±10% of nominal value over a power line variation of 85 volts to 140 volts (for a nominal 120 v.a.c. line).

It is also an objective of the present invention to eliminate leakage current problems by providing the adaptive clamp circuit **24** which is shown in more detail in the FIGS. **6**a and **6**b. The power input lines **22** are connected directly through the adaptive clamp circuit **24** to the clamp circuit output lines **26**. The adaptive clamp circuit **24** monitors the input voltage feeding the LED array **12** on the input lines **22** with a voltage sensing means **48** connected across the lines **22** and loads the input lines resistively with a low impedance controlled load means **50**, connected across the output lines **26**, whenever the line voltage is below some critical amount (typically 40 volts a.c. r.m.s.). The adaptive clamp circuit **24** assumes that voltages lower than a certain value (typically 40 volts) are due to leakage currents through the solid state control relay or switch. The adaptive clamp circuit **24** loads the lines with a resistor to draw current, forcing the leakage voltage to a lower voltage (typically on the order of 10 volts a.c.) that will not cause problems for the conflict monitor or power factor correction (p.f.c.) circuit. Most traffic signals must be capable of being flashed (at least the red and yellow signals) from the traffic controller electronics. It has been found experimentally that residual leakage currents interfere with the ability to flash signals that are equipped with power factor correction circuits. The adaptive clamp circuit **24** prevents this problem by allowing the p.f.c. circuit to completely discharge between power line pulses which flash the signal at a nominal sixty flashes per minute. In summary, the adaptive clamp circuit **24** performs two functions by reduc-

ing the leakage voltage: 1) it provides a reactance free means to eliminate problems with conflict monitors (while preventing poor power factors); and 2) it allows the p.f.c. circuit to properly flash the LED array signal **12**.

The adaptive clamp circuit **24** is shown in more detail in the FIG. **6**b wherein a first pair of diodes D**3** and D**4** has anodes connected to the lines **22** and cathodes connected together. A second pair of diodes D**1** and D**2** has cathodes connected to the lines **26** and anodes connected together. A first resistor (R**1**) **52** is connected between the junction of the second pair of diodes D**1** and D**2** and an anode of a Zener diode D**5**. The Zener diode D**5** has a cathode connected to the junction of the first pair of diodes D**3** and D**4**. A second resistor (R**2**) **54** is connected between the anode of the Zener diode D**5** and a base of a first NPN transistor Q**1**. The transistor Q**1** has an emitter connected to the junction of the second pair of diodes D**1** and D**2** and a collector connected through a third resistor (R**3**) **56** to the junction of the first pair of diodes D**3** and D**4**. A fourth resistor (R**4**) **58** is connected between the collector of the transistor Q**1** and a base of a second NPN transistor Q**2**. The transistor Q**2** has an emitter connected to the junction of the second pair of diodes D**1** and D**2** and a collector connected through a fifth resistor (R**5**) **60** to the junction of the first pair of diodes D**3** and D**4**.

The optional adaptive clamping circuit **24** is advantageously placed across the input terminals of the p.f.c., switchmode power supply **10** as shown in the FIG. **5**. As noted above, as a consequence of using solid state relays or switches in signal controllers, the power to the signals is not fully disconnected (even when the signal should be off). This leakage current often causes problems with safety devices such as electronic conflict monitors. Additionally, these leakage currents may present problems during flashing operation of LED signals, as the power supply circuits may not be fully discharged between flashes. Switchmode, p.f.c. power suppliers of the type proposed for the present invention are particularly sensitive to such leakage currents and will be inhibited from flashing LEDs at an acceptable rate (55 to 60 flashes per minute).

In current practice, these leakage currents are minimized by "short circuiting" them by means of a reactive, non dissipative element. The input capacitor (typically 1–2 μF), as shown in the FIG. **3** for example, performs this function. However this same capacitor is across the line when the LED array signal is energized, drawing reactive power and contributing to a poor power factor.

Another feature of the present invention is to provide for an adaptive line loading means or clamp that switches itself in or out of circuit as needed. As shown in the FIG. **6**b, the adaptive clamp circuit **24** monitors the line voltage, and when only leakage currents are present that drop the line voltage to about 40 v.a.c. the circuit applies a resistive load **60** across the lines **22** by turning on the solid-state switch Q**2**. When the lines **22** are loaded by the fifth resistor **60**, having a suitable value (typically 1 kOhm), the leakage voltage will drop to under 10 volts. At this depressed voltage, the p.f.c. switchmode converter is fully off, and can properly flash the LEDs **14** at the requisite rate.

This adaptive clamp **24** can of course be used with other types of power supplies where the addition of reactive elements could degrade the power factor. The clamping circuit **24** works by using the sensing transistor Q**1** and the Zener diode D**5** (the voltage sensing means **48** of the FIG. **6**a) to determine if the line voltage is below a certain magnitude (typically 40 volts). The sensing transistor Q**1** and the Zener diode D**5** are the voltage sensing means **48** of the FIG. **6**a. If the Zener diode D**5** does not conduct, the transistor Q**2** is turned on to place the load resistor **60** the power lines **22** causing the leakage voltage to drop below 10 volts. The transistor Q**2** and the resistor **60** are the controlled load means **50** of the FIG. **6**a. Whenever the traffic signal controller relay "closes", the line voltage appearing at the input to the adaptive clamping circuit **24** rises to nominally 120 volts and the sensing circuit (Q**1** and D**5**) turn off the controlling transistor Q**2**, removing the resistor **60** from the circuit thereby preventing unnecessary dissipation of power. Since there are no reactances involved, this circuit does not influence the power factor reflected at the a.c. input lines **22**.

Another aspect of the present invention is the use of a d.c. input (instead of the a.c. power line) as a power backup feature that is activated upon power line loss. Conventional practice employs battery driven a.c. inverters to generate the backup power upon line failure. Such inverters are expensive, inefficient and are failure prone. The use of battery power (d.c.) to directly energize the regulated switchmode power supply that powers the LED array signal is very cost effective and energy efficient. The wide input voltage range of most switchmode power supplies allows the batteries to be used optimally as they can be virtually fully discharged in the power backup cycle yielding very good use of battery capacity. Lower cost, smaller batteries are therefore useable.

As noted previously, the use of a direct line operated, non-transformer isolated converter to power the LED array signal allows d.c. power to be used (instead of a.c.) in case of line failure. Using batteries without having to rely on an inverter to perform the d.c. to a.c. conversion is novel, extremely reliable, and cost effective. The importance of battery backup for critical traffic signals is obvious, and the need for reliability is also apparent. As shown in the FIG. **7**, a battery backup system **62** includes a temperature compensated, line powered automatic battery charger **64** having an input connected to the lines **22** and an output connected to an input of a rechargeable battery **66** to keep the battery fully charged at all times that a.c. power is available. Temperature compensation can be used to stop the charging process to extend the life of the battery, as it is well known that the optimal end point charging voltage for most secondary cells is a function of temperature.

Because of the critical safety nature of these devices, an automatic battery testing circuit and load **68** is built into the battery backup system **62**. Deterioration of the battery **66**, which is inevitable ova time, is thereby monitored and degradation past a certain point is nagged or announced. The testing circuit **68** has an input connected to an output of the battery **66** for sensing battery voltage. An alarm signal line **70** is connected to an output of the circuit **68** for generating the alarm signal and a set flag signal line **72** is connected to another output of the circuit **68** for generating the set flag signal. A control line **74** is connected between an output of the circuit **68** and an input of the battery **66**. Secondary batteries that are kept in float service for any length of time tend to degrade and loose capacity. This deterioration is far more apparent in high temperature environments, and can adversely affect the safety margins of the backup power supply. That is. instead of providing 8 to 10 hours of flashing red LED array signal backup service, a degraded battery might only last a few hours. Determining the actual condition or serviceability of a storage battery is difficult, because a measurement of terminal voltage does not necessarily indicate loss of capacity. It has been experimentally determined that a good measure of battery capacity can be made by loading the battery with a substantial current (typically 5–10 amperes)

for several minutes and measuring the terminal voltage under load. Naturally the battery charger is inhibited during this test. This method is well recognized as a good diagnostic test as it depletes any "surface charge" on the electrodes and more accurately indicates remaining battery ampere-hours.

A voltage comparator circuit in the battery testing circuit and load **68** establishes an "accept" or "reject" level for the battery **66** as it is tested every 24 hours or so. In order to accommodate partly discharged cells, two sequential, battery tests that result in a "reject" are registered in a latch which may trigger a visual or audible alarm signal on the line **70**. Alternatively, a relay or contact closure (flag) may be set to generate a signal on the line **72** so that a data modem can relay the degraded battery information to a central service facility. Of course, such calls or alarm signals are triggered well before the battery is no longer serviceable so that safety is not comprised.

A line failure detection circuit **76** has an input connected to the power lines **22** and another input connected to an output of the battery **66** to receive operating power from the battery. The circuit **76** initiates the power switch-over process whenever a.c. input power is disconnected. An output of the line failure detection circuit **76** is connected to an input of a time delay and restoration circuit **78** which has another input connected to an output of the battery **66** to receive operating power from the battery. The time delay function ensures that short, transient line dropouts are disregarded. An output of the time delay and restoration circuit **78** is connected to an input of a d.c. power switch-over and flasher circuit **80** which has another input connected to an output of the battery **66** to receive operating power from the battery. Outputs of the circuit **80** are connected to a first set of input terminals of a switch-over relay **82**. The relay has a second set of terminals connected to red signal outputs of a traffic controller **84** having an input connected to the power lines **22**. Output terminals of the switch-over relay **82** are connected to the input of the switchmode converter power supply **10** which is connected to the red LED array signal **12**. Normally, the switch-over relay **82** is in the position shown to connect a.c. power on the lines **22** through the traffic controller **84** to the power supply **10**.

Generally, line loss in excess of **250** msec will cause the d.c. power switch-over relay **82** to switch the output terminals to disconnect the power supply **10** and the red LED array signal **10** from the traffic controller **84** (and the a.c. feed) and connect them to the d.c. battery **66** through the d.c. power switch-over and flasher circuit **80**. Note that the d.c. supply is flashed or pulsed by the circuit **80** at a nominal rate of 60 pulses per minute (1 Hz) to place all the red LED array signals at an intersection in a flashing mode, effecting a four way stop. While an electromechanical switch-over relay **82** is shown for complete isolation of the existing traffic controller **84** and the battery backup system **62**, solid state devices could be used.

Whenever the line power is restored, the time delay and restoration circuit **78** will wait some period (typically 10–15 seconds) before the LED array signal **12** is switched back to the a.c. power mode. This delay avoids the many transients that usually accompany a.c. line restoration after a power outage. Note that no inverter is employed in this system, as is common practice in existing commercial hardware. The inefficiency and poor reliability of d.c. to a.c. converters is thereby avoided. Because the switchmode power supply **10** can accommodate wide variations in input voltage (both a.c. and d.c.) the storage battery **66** can be discharged virtually completely while maintaining essentially constant luminosity of the LED array signal **12**.

Additionally, as shown in the FIG. **7**, there are provisions for the introduction of narrow "marker pulses" superimposed on the d.c. supply for use as synchronizing pulses. An optional synchronizing pulse generator **86** has an output connected to an input of the d.c. power switch-over and flasher circuit **80** for generating such pulses. This optional feature permits a number of LED array signals that are pulse modulated to operate in sync in the absence of the 60 Hz a.c. line signal. These "marker pulses" are essentially short (200 μsec) power dropouts that do not affect the operation of the LED array signal **12**, but are easily extracted at the signal to effect pulse synchronization of several pulsed LED array signals.

As noted above, the lack of input transformers or series capacitors before the full wave bridge, allows d.c. power to be applied at the input terminals of the power supply **10** in lieu of a.c. power. Since there are no reactive (a.c.) components in the input circuitry, proper operation of the switchmode converter is maintained, and output voltage regulation is still available. Obviously, the p.f.c. portion of the circuit **10** will be nonfunctional during operation on d.c. input power. As shown, the switchmode convener will provide an essentially constant output voltage (nom. 100 volts d.c.) to the LED array **12** over a range of a.c. input voltages from 85 volts r.m.s. to 140 volts r.m.s. and over a d.c. input voltage range of 38 volts d.c. to 65 volts d.c. The wide (input voltage) operating range allows rechargeable batteries to be used very efficiently, since their capacity can be fully utilized in the discharge cycle, as their terminal voltage drops.

As discussed above, LED signals are being used to replace incandescent lamps in many applications. Traffic signals are among the more common devices that are being upgraded for with LEDs because of the tremendous power savings and the dramatic improvement in service life. In most cases the incandescent lamps are merely replaced with an integral LED retrofit assembly that does not require any modification of the existing traffic signal housing or the drive and control circuitry associated with the signal. That is, users expect the LED retrofit lamps to operate normally without added modifications to the housing or traffic controller.

One aspect of this conversion to LED signals from incandescent lamps poses significant problems however. Many existing incandescent lamp traffic signals are dimmed at night to reduce glare and, of course, power consumption. LED signals can be dimmed by reducing the average current through the LED array. A problem arises however because existing traffic signal controllers dim incandescent signals by providing half-wave rectified a.c. to the devices. Normally the traffic lamps are powered by switched a.c. line power which has, in virtually all cases, a sinusoidal wave form. Simply rectifying this power allows the traffic signal controller to reduce the average voltage and current to the load in a loss free manner. This technique has been in common use for many years and has become the "defacto" standard dimming technique.

Most LED traffic signals do not work satisfactorily with half wave rectified a.c.; in fact, many simply do not light. Some LED lamp arrays which are equipped with regulated power supplies will illuminate satisfactorily when powered by half wave rectified a.c. current, but they do not dim. The regulated power supplies accept the half wave rectified a.c. line power and treat it merely as a low line voltage and correct for this phenomenon. The voltage impressed across the LED array is kept relatively constant in spite of such input voltage variations thereby keeping the LED luminous output essentially unchanged, i.e. undimmed.

Certain switchmode, regulating power supplies are able to power LED signals satisfactorily from even half wave rectified a.c. power supplies. A half wave detector circuit in the LED signal power supply can determine whether the traffic signal controller is sending a "dimming" command. Upon detection of this half wave signal, the switchmode power supply can be programmed or adjusted to reduce its output voltage to the LED array. By adjusting either the pulse width or the frequency (at constant pulse width) of the switchmode power supply, the output voltage (and/or current) can be reduced in an efficient, nondissipative manner.

Alternatively, the half wave detector can be used to change the average current through the LED array by reducing the effective pulse width of a pulse width modulation controller that drives the LEDs. In either method, the average LED current and intensity are reduced in response to the detection of a half wave rectified input current. In this way, the LED signal is "transparent" to the user who may now utilize the LED device in the same manner as conventional incandescent signals.

As shown in the FIG. **5**, a half wave power detector circuit **88** has inputs connected to the inputs of the full wave rectifier **32** at the clamp circuit output lines **26** to monitor the input a.c. power on the power input lines **22** to the power supply **10**. The detector **88** has an output connected to a control signal line **90** which is connected to an input of the control I.C. **40**. The detector **88** generates a control signal on the line **90** in response to the detection of a half wave dimming signal on the a.c. power lines **22**. The control signal is directed to the power supply regulator circuit **38**, where it causes the output voltage of the switchmode power supply **10** to be reduced in response to the dimming command. For current regulated power supplies, the average output current to the LED arrays can be reduced to effect dimming. In cases where the LED array is powered by a pulse width modulator, such as the modulator **46**, the connection of the line **90** to the control I.C. **40** is eliminated and the output of the detector **88** is connected by a control signal line **92** to an input of the modulator **46** such that the average current delivered to the LED array may be reduced by decreasing the pulse width of the modulator.

All such dimming methods have one key feature in common; the average current through the LED signal **12** is decreased in response to the detection of a half wave dimming signal impressed on the power supply input lines **22**. The detection of half wave power by the detector **88** causes the LED power supply **10** to either adjust the output pulse width at constant frequency or adjust the frequency at constant pulse width. The power supply **10** can be any type of power supply which converts a.c. power to d.c. power suitable for illuminating the LED array **12**.

The present invention is an apparatus **10** for supplying regulated voltage d.c. electrical power to an LED array including a rectifier means **32** having an input and an output, the rectifier means **32** being responsive to a.c. power at the input for generating rectified d.c. power at the output, a power factor correction converter means **38** having an input connected to the rectifier means **32** output and an output, the power factor correction converter means **38** being responsive to the rectified d.c. power at the power factor correction converter means input for generating regulated voltage, power factor corrected d.c. power at the power factor correction converter means output, and an LED array **12** having an input connected to the power factor correction converter means **38** output for receiving the power factor corrected d.c. power to illuminate the LED array **12**. The power factor correction converter means **38** can be a power factor correcting and voltage regulating buck/boost switchmode converter.

The apparatus **10** includes a pulse width modulated modulator means **46** connected to the power factor correction converter means **38** output and the LED array **12** input for modulating the power factor corrected d.c. power and an electromagnetic interference filter means **28** connected to the full wave rectifier means **32** input for preventing conducted interference from feeding back onto a.c. power lines **22** connected to the rectifier means **32** input. The apparatus **10** also includes an adaptive clamp circuit means **24** connected to the rectifier means **32** input for eliminating leakage current problems. The adaptive clamp circuit means **24** has an input adapted to be connected to a pair of a.c. power lines **22**, a pair of clamp circuit output lines **26** connected to the adaptive clamp circuit means **24** input, a voltage sensing means **48** connected across the adaptive clamp circuit means **24** input, and a controlled load means **50** connected across the clamp circuit output lines **26** and to the voltage sensing means **48**. The voltage sensing means **48** is responsive to a magnitude of a.c. voltage at the adaptive clamp circuit means **24** input lower than a predetermined magnitude for turning on the controlled load means **50** to connect a low impedance load **60** in the controlled load means **50** across the clamp circuit output lines **26** and the voltage sensing means **48** is responsive to a magnitude of the a.c. voltage at the adaptive clamp circuit means **24** input equal to or greater than the predetermined magnitude for turning off the controlled load means **50** to disconnect the low impedance load **60** from the clamp circuit output lines **26**.

The apparatus **10** further includes a battery backup means **62** having an input for receiving a.c. power applied to the rectifier means **32** input and having an output at which d.c. power is generated, and a switch-over means **82** connected to the battery backup means **62** output and to the rectifier means **32** input, the battery backup means **62** being responsive to a failure of a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to connect the battery backup means **62** output to the rectifier means **32** input to provide d.c. power to illuminate the LED array **12** and being responsive to a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to disconnect the battery backup means **62** output from the rectifier means **32** input. The switch-over means **82** can be an electromechanical relay. The battery backup means **62** includes a time delay and restoration means **78** responsive to application of a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to disconnect the battery backup means **62** output from the rectifier means **32** input and connect the a.c. power to the rectifier means **32** input after a predetermined time delay. The battery backup means **62** also includes a d.c. power switch-over and flasher means **80** connected to the switch-over means **82** for pulsing the d.c. power at a predetermined rate to flash the LED array **12** and a synchronizing pulse generator means **86** connected to the d.c. power switch-over and flasher means **80** for imposing marker pulses on the d.c. power at a predetermined rate.

The apparatus **10** also includes a half wave power detector means **88** having an input connected to the input of the rectifier means **32** and an output connected to another input of the power factor correction converter means **38**, the half wave power detector means being responsive to a dimming signal at the rectifier means input for generating a control signal at said half wave power detector means output and the power factor correction converter means **38** being responsive to the control signal for decreasing the regulated d.c. power to dim the LED array **12**. If the apparatus **10** includes the pulse width modulated modulator means **46** connected to the

power factor correction converter means **38** output and the LED array **12** input for modulating the regulated voltage d.c. power, the half wave power detector means **88** has its output connected to an input of the pulse width modulated modulator means **46** and is responsive to a dimming signal at the rectifier means input for generating a control signal at the half wave power detector means output and the pulse width modulated modulator means **46** is responsive to the control signal for decreasing the regulated d.c. power to dim the LED array **12**.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.

What is claimed is:

[**1**. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means (**32**) having an input and an output, said rectifier means (**32**) being responsive to a.c. power at said input for generating rectified d.c. power at said output;

a power factor correction converter means (**38**) having an input connected to said output of said rectifier means (**32**) and an output, said power factor correction converter means (**38**) being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction convener means output; and

an LED array (**12**) having an input connected to said output of said power factor correction converter means (**38**) for receiving said regulated voltage d.c. power to illuminate said LED array (**12**).]

[**2**. The apparatus according to claim **1** wherein said power factor correction converter means (**38**) is a power factor correcting and voltage regulating buck/boost switchmode converter.]

[**3**. The apparatus according to claim **1** including a pulse width modulated modulator means (**46**) connected to said output of said power factor correction converter means (**38**) and to said input of said LED array (**12**) for modulating said regulated voltage d.c. power.]

[**4**. The apparatus according to claim **1** including an electromagnetic interference filter means (**28**) connected to said input of said rectifier means (**32**) for preventing conducted interference from feeding back onto a.c. power lines (**22**) connected to said rectifier means input.]

[**5**. The apparatus according to claim **1** including an adaptive clamp circuit means (**24**) connected to said input of said rectifier means (**32**) for eliminating leakage current problems.]

[**6**. The apparatus according to claim **5** wherein said adaptive clamp circuit means (**24**) has an input adapted to be connected to a pair of a.c. power lines (**22**), a pair of clamp circuit output lines (**26**) connected to said adaptive clamp circuit means input, a voltage sensing means (**48**) connected across said input of said adaptive clamp circuit means (**24**), and a controlled load means (**50**) connected across said clamp circuit output lines (**26**) and to said voltage sensing means (**48**), said voltage sensing means (**48**) being responsive to a magnitude of a.c. voltage at said adaptive clamp circuit means input lower than a predetermined magnitude for turning on said controlled load means (**50**) to connect a low impedance load (**60**) in said controlled load means (**50**) across said clamp circuit output lines (**26**) and said voltage sensing means (**48**) being responsive to a magnitude of the a.c. voltage at said adaptive clamp circuit means input equal to or greater than said predetermined magnitude for turning off said controlled load means (**50**) to disconnect said low impedance load (**60**) from said clamp circuit output lines (**26**).]

[**7**. The apparatus according to claim **1** including a battery backup means (**62**) having an input for receiving a.c. power applied to said input of said rectifier means (**32**) and having an output at which d.c. power is generated, and a switchover means (**82**) connected to said output of said battery backup means (**62**) and to said rectifier means input, said battery backup means (**62**) being responsive to a failure of a.c. power at said battery backup means input for controlling said switch-over means (**82**) to connect said output of said battery backup means (**62**) to said input of said rectifier means (**32**) to provide d.c. power to illuminate said LED array (**12**) and being responsive to a.c. power at said battery backup means input for controlling said switch-over means (**82**) to disconnect said battery backup means output from said rectifier means input.]

[**8**. The apparatus according to claim **7** wherein said switch-over means (**82**) is an electromechanical relay.]

[**9**. The apparatus according to claim **7** wherein said battery backup means (**62**) includes a time delay and restoration means (**78**) responsive to application of a.c. power at said input of said battery backup means (**62**) for controlling said switch-over means (**82**) to disconnect said output of said battery backup means (**62**) from said input of said full wave rectifier means (**32**) and connect the a.c. power to said full wave rectifier means input after a predetermined time delay.]

[**10**. The apparatus according to claim **7** wherein said battery backup means (**62**) includes a d.c. power switch-over and flasher means (**80**) connected to said switch-over means (**82**) for pulsing said d.c. power at a predetermined rate to flash said LED array (**12**).]

[**11**. The apparatus according to claim **7** wherein said battery backup means (**62**) includes a synchronizing pulse generator means (**86**) connected to said d.c. power switchover and flasher means (**80**) for imposing marker pulses on said d.c. power at a predetermined rate.]

[**12**. The apparatus according to claim **1** including a half wave power detector means (**88**) having an input connected to said input of said rectifier means (**32**) and an output connected to another input of said power factor correction converter means (**38**), said half wave power detector means (**88**) being responsive to a dimming signal at said rectifier means input for generating a control signal at said half wave power detector means output and said power factor correction converter means (**38**) being responsive to said control signal for decreasing said regulated d.c. power to dim said LED array (**12**).]

[**13**. The apparatus according to claim **1** including a pulse width modulated modulator means (**46**) connected to said output of said power factor correction converter means (**38**) and to said input of said LED array (**12**) for modulating said regulated voltage d.c. power and a half wave power detector means (**88**) having an input connected to said input of said rectifier means (**32**) and an output connected to an input of said pulse width modulated modulator means (**46**), said half wave power detector means being responsive to a dimming signal at said rectifier means input for generating a control signal at said half wave power detector means output and said pulse width modulated modulator means (**46**) being responsive to said control signal for decreasing said regulated d.c. power to dim said LED array (**12**).]

[**14**. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a power supply means (**10**) having an input and an output, said power supply means (**10**) being responsive to a.c. power at said input for generating regulated voltage d.c. power at said output to illuminate an LED array (**12**) connected to said power supply means output; and

a dimming detector means (**88**) having an input connected to said input of said power supply means (**10**) and an output connected to another input of said power supply means (**10**), said dimming detector means (**88**) being responsive to a dimming signal at said power supply means input for generating a control signal at said dimming detector means output and said power supply means (**10**) being responsive to said control signal for decreasing said regulated voltage d.c. power to dim the LED array (**12**).]

[**15**. The apparatus according to claim **14** wherein said dimming detector means (**88**) is a half wave power detector means, said dimming signal is half wave rectified a.c. power and said power supply means (**10**) includes a rectifier means (**32**) having an input connected to said power supply means input and an output and a power factor correction converter means (**38**) having an input connected to said rectifier means output and an output connected to said power supply output, said power factor correction converter means (**38**) including said another input of said power supply means (**10**), said power factor correction convener means (**38**) being responsive to said control signal for decreasing said regulated voltage d.c. power to dim the LED array (**12**).]

[**16**. The apparatus according to claim **14** wherein said dimming detector means (**88**) is a half wave power detector means, said dimming signal is half wave rectified a.c. power and including a pulse width modulated modulator means (**46**) connected to said output of said power supply means (**10**) for modulating said regulated voltage d.c. power, said pulse width modulated modulator means (**46**) including said another input of said power supply means (**10**), said pulse width modulated modulator means (**46**) being responsive to said control signal for decreasing said regulated voltage d.c. power to dim the LED array (**12**).]

[**17**. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means (**32**) having an input and an output, said rectifier means (**32**) being responsive to a.c. power at said input for generating rectified d.c. power at said output;

a power factor correction converter means (**38**) having an input connected to said output of said rectifier means (**32**) and an output, said power factor correction converter means (**38**) being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction converter means output;

a battery backup means (**62**) having an input for receiving a.c. power applied to said input of said rectifier means (**32**) and having an output at which d.c. power is generated; and

a switch-over means (**82**) connected to said output of said battery backup means (**62**) and to said input of said rectifier means (**32**), said battery backup means (**62**) being responsive to a failure of a.c. power at said battery backup means input for controlling said switchover means (**82**) to connect said battery backup means output to said rectifier means input to provide d.c. power to said power factor correction converter means (**38**) to illuminate an LED array connected to said output of said power factor correction converter means (**38**) and being responsive to a.c. power at said battery backup means input for controlling said switch-over means (**82**) to disconnect said battery backup means output from said rectifier means input.]

[**18**. The apparatus according to claim **17** wherein said power correction converter means (**38**) is a power factor correcting and voltage regulating buck/boost switchmode converter.]

[**19**. The apparatus according to claim **17** including an adaptive clamp circuit means (**24**) connected to said input of said rectifier means (**32**) for eliminating leakage current problems, said adaptive clamp circuit means (**24**) having an input adapted to be connected to a pair of a.c. power lines (**22**), a pair of clamp circuit output lines (**26**) connected to said adaptive clamp circuit means input, a voltage sensing means (**48**) connected across said adaptive clamp circuit means input, and a controlled load means (**50**) connected across said clamp circuit output lines (**26**) and to said voltage sensing means (**48**), said voltage sensing means (**48**) being responsive to a magnitude of a.c. voltage at said adaptive clamp circuit means input lower than a predetermined magnitude for turning on said controlled load means (**50**) to connect a low impedance load (**60**) in said controlled load means (**50**) across said clamp circuit output lines (**26**) and said voltage sensing means (**48**) being responsive to a magnitude of the a.c. voltage at said adaptive clamp circuit means input equal to or greater than said predetermined magnitude for turning off said controlled load means (**50**) to disconnect said low impedance load (**60**) from said clamp circuit output lines (**26**).]

[**20**. The apparatus according to claim **17** wherein said battery backup means (**62**) includes a time delay and restoration means (**78**) responsive to application of a.c. power at said input of said battery backup means (**62**) for controlling said switch-over means (**82**) to disconnect said output of said battery backup means (**62**) from said input of said rectifier means (**32**) and connect the a.c. power to said rectifier means input after a predetermined time delay.]

[**21**. The apparatus according to claim **17** wherein said battery backup means (**62**) includes a d.c. power switch-over and flasher means (**80**) connected to said switch-over means (**82**) for pulsing said d.c. power at a predetermined rate to flash said LED array (**12**).]

[**22**. The apparatus according to claim **17** Wherein said battery backup means (**62**) includes a synchronizing pulse generator means (**86**) connected to said d.c. power switchover and flasher means (**80**) for imposing marker pulses on said d.c. power at a predetermined rate.]

[**23**. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means (**32**) having an input and an output, said rectifier means (**32**) being responsive to a.c. power at said input for generating rectified d.c. power at said output;

a power factor correcting and voltage regulating buck/boost switchmode converter (**38**) having an input connected to said output of said rectifier means (**32**) and an output, said switchmode converter (**38**) being responsive to said rectified d.c. power at said switchmode converter input for generating regulated voltage d.c. power at said switchmode converter output;

an LED array (**12**) having an input connected to said output of said switchmode converter (**38**) for receiving said regulated voltage d.c. power to illuminate said LED array (**12**);

a battery backup means (**62**) having an input for receiving a.c. power applied to said input of said rectifier means (**32**) and having an output at which d.c. power is generated; and

a switch-over means (**82**) connected to said output of said battery backup means (**62**) and to said input of said rectifier means (**32**), said battery backup means (**62**) being responsive to a failure of a.c. power at said battery backup means input for controlling said switchover means (**82**) to connect said battery backup means output to said rectifier means input to provide d.c. power to said switchmode converter (**38**) to illuminate said LED array (**12**) and being responsive to a.c. power at said battery backup means input for controlling said switch-over means (**82**) to disconnect said battery backup means output from said rectifier means input.**]**

24. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage through a solid state traffic controller switch for providing an electrical input voltage having an operating range with a lower limit voltage sufficient to activate the LEDs when the switch is on;

a rectifier coupled to the electrical input and having a rectifier output;

a line voltage regulating switchmode power supply having a power supply input coupled to the rectifier output and a power supply output;

a plurality of LEDs coupled to the power supply output and having multiple current paths for emitting light in response to the power supply output; and

a conflict monitor compatibility circuit including a low impedance load and a transistor in series connection with the low impedance load, the transistor being biased as a switch having an essentially nonconductive condition whenever the electrical input voltage is at or above the operating range lower limit voltage and an essentially conductive condition if the electrical input voltage drops to a predetermined value below the operating range lower limit voltage, wherein:

the transistor in the essentially nonconductive condition prevents dissipation of power from the power supply output through the low impedance load whenever the electrical input voltage is within the operating range, and

the transistor in the essentially conductive condition couples the low impedance load to the electrical input for shunting leakage current from the solid state traffic controller switch when the switch is off.

25. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage through a solid state traffic controller switch for providing an electrical input voltage having an operating range with a lower limit voltage sufficient to activate the LEDs when the switch is on;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply for maintaining current and voltage waveforms substantially in phase and for providing a regulated current output with respect to variations in the input line voltage, the power supply having a power supply input coupled to the rectifier output and a power supply output;

a plurality of LEDs coupled to the power supply output and having multiple current paths for emitting light in response to the power supply output; and

a conflict monitor compatibility circuit including a low impedance load and a transistor in series connection with the low impedance load, the transistor being biased as a switch having an essentially nonconductive condition whenever the electrical input voltage is at or above the operating range lower limit voltage and an essentially conductive condition if the electrical input voltage drops to a predetermined value below the operating range lower limit voltage, wherein:

the transistor in the essentially nonconductive condition prevents dissipation of power from the power supply output through the low impedance load whenever the electrical input voltage is within the operating range, and

the transistor in the essentially conductive condition couples the low impedance load to the electrical input for shunting leakage current from the solid state traffic controller switch when the switch is off.

26. A power supply assembly for powering light emitting diodes (LEDs) in an outdoor line-connected signal, comprising:

an electrical input for coupling to a source of a.c. line voltage through a solid state traffic controller switch for providing an electrical input voltage having an operating range with a lower limit voltage sufficient to activate the LEDs when the switch is on;

a rectifier coupled to the electrical input and having a rectifier output;

a switchmode power supply for improving poor power factor, whereby the power supply provides essentially constant current at a power supply output with respect to variations in line voltage input, and whereby current and voltage waveforms are maintained substantially in phase, the power supply having a power supply input coupled to the rectifier output and a power supply output;

a plurality of LEDs coupled to the power supply output and having multiple current paths for emitting light in response to the power supply output; and

a conflict monitor compatibility circuit including a low impedance load and a transistor in series connection with the low impedance load, the transistor being biased as a switch having an essentially nonconductive condition whenever the electrical input voltage is at or above the operating range lower limit voltage and an essentially conductive condition if the electrical input voltage drops to a predetermined value below the operating range lower limit voltage, wherein:

the transistor in the essentially nonconductive condition prevents dissipation of power from the power supply output through the low impedance load whenever the electrical input voltage is within the operating range, and

the transistor in the essentially conductive condition couples the low impedance load to the electrical input for shunting leakage current from the solid state traffic controller switch when the switch is off.

27. The assembly according to claim 24, 25 or 26 wherein the switchmode power supply comprises an integrated circuit power supply.

28. The assembly of claim 27 wherein the integrated circuit power supply comprises a power factor correcting switchmode converter integrated circuit.

29. The assembly according to claim 24, 25 or 26 wherein the plurality of LEDs comprise a plurality of series-parallel connected LEDs arranged in strings.

30. The assembly according to claim 29 wherein the plurality of LEDs comprise a ballast resistor in each string.

31. A conflict monitor compatibility circuit for use in traffic and pedestrian signaling applications, comprising:

a plurality of LEDs for emitting light in response to an electrical input adapted to be coupled to a source of a.c. line voltage through a solid state traffic controller switch for providing an electrical input voltage having an operating range with a lower limit voltage sufficient to activate the LEDs when the switch is on;

a transistor biased as a switch that has an essentially nonconductive condition whenever the electrical input voltage is at or above the operating range lower limit voltage and an essentially conductive condition if the electrical input voltage drops to a predetermined value below the operating range lower limit voltage; and

a low impedance load in series connection with the transistor, wherein:

the transistor in the essentially nonconductive condition prevents dissipation of power through the low impedance load whenever the electrical input voltage is within the operating range, and

the transistor in the essentially conductive condition couples the low impedance load to the electrical input for shunting leakage current from the solid state traffic controller switch when the switch is off.

32. The assembly according to claim 24, 25, or 26, wherein the conflict monitor compatibility circuit further includes a sensor for providing a control output if the electrical input voltage drops below the predetermined value and a control element for switching the transistor to the essentially conductive condition in response to the control output.

33. The assembly according to claim 32, wherein the sensor is a Zener diode that conducts in a reverse direction only at voltages above the predetermined value.

34. The assembly according to claim 33, wherein the control element is a second transistor biased as a switch and having a base coupled to the Zener diode.

35. The assembly according to claim 24, 25, or 26, further comprising an electromagnetic interference filter coupled to the power supply for preventing conducted interference from feeding back onto the a.c. line.

36. The assembly according to claim 24, 25, or 26, further comprising a traffic, pedestrian or rail crossing signal housing enclosing the assembly.

37. The conflict monitor compatibility circuit according claim 31, further comprising a sensor for providing a control output if the electrical input voltage drops below the predetermined value and a control element for switching the transistor to the essentially conductive condition in response to the control output.

38. The conflict monitor compatibility circuit according to claim 37, wherein the sensor is a Zener diode that conducts in a reverse direction only at voltages above the predetermined value.

39. The conflict monitor compatibility circuit according to claim 38, wherein the control element is a second transistor biased as a switch and having a base coupled to the Zener diode.

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